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A STUDY OF SELECTED ECONOMIC AND ENVIRONMENTAL ASPECTS OF INDIVIDUAL HOME WASTEWATER TREATMENT SYSTEMS

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A review of individual home wastewater treatment system technology, emphasizing soil absorption systems, indicates the full potential of individual treatment is not being realized. Current system design, installation, and operational practices do not reflect what is known about sewage-soil interactions. A focusing activity for resolving some important technological and institutional uncertainties is needed. A reintroduction of individual system technology on a widespread basis where applicable would result in an estimated reduction of over $3 billion (present value) in the total cost of providing treatment to the new individual home population in the 1970-1990 period.

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ABSTRACT

A review of individual home wastewater treatment system technology, emphasizing soil absorption systems, indicates the full potential of individual treatment is not being realized. Current system design, installation, and operational practices do not reflect what is known about sewage-soil interactions. A controlled demonstration program is suggested as a focusing activity for resolving some important technological and institutional uncertainties. A reintroduction of individual system technology on a widespread basis where applicable would result in an estimated reduction of over $3 billion (present value) in the total cost of providing treatment to the new individual home population in the 1970-1990 period.

SUMMARY

CURRENT IMAGE OF INDIVIDUAL SYSTEMS

Individual solutions to the disposal of sewage from households date to antiquity, but they were gradually replaced by centralized systems for the collection, conveyance, and treatment of household wastes as the need to control health hazards became apparent and as the means to do so became available. In the housing boom period which followed World War II, the demand for housing outstripped the ability to supply sewer and central treatment plant services, and the unsatisfied demand was generally met by providing septic tanks and cesspools. The available information on such systems was largely based on what was thought to be true rather than on what was known to be true, and in many cases, scant attention was paid even to the available information in the rush to build and sell. The resulting rash of failures of septic systems in many communities became ever more visible as the federal government became involved as a guarantor of home mortgages and was left with the responsibility of housing that had become unliveable because of individual sewage system failures. The net result has been a badly tarnished image of septic tanks, and most sanitarians and other public health officials regard individual home treatment as a last resort when sewer systems are not available or a temporary expedient until they are.

TECHNICAL CONSIDERATIONS IN SYSTEM FAILURES

The most fragile and critical part of individual home treatment systems which use ground disposal is the soil absorption system. Septic tanks rarely fail structurally, but if the sludge and scum byproducts of sewage digestion are allowed to accumulate and fill the tank beyond a critical range, excess suspended solids and incompletely degraded materials will be carried over to the soil absorption system, where they will accelerate the soil clogging mechanisms and quickly ruin the absorption field. Even under the most benign conditions of installation, use, and maintenance, the soil system can experience "creeping failure" unless provisions are made for alternating periods of inundation with long periods of rest to permit the regaining of absorptive capacity.*

While physical and chemical mechanisms can accelerate the clogging process, the long-term clogging is probably attributable in a large percentage of cases mainly to microbial processes which take place at the oxygen-poor interface between tank effluent and soil. A clogging mat develops in about the first centimeter of the soil, and the infiltrative capacity of this mat is thought to exert more control over the passage of liquid than does the percolative capacity of the bulk soil. This phenomenon plus the extreme variability of conditions under which soil percolation tests are run and the apparently even greater variability of results of replicated percolation tests run under standardized conditions indicate that a better measure of soil suitability than the percolation test is required for the design of reliable subsurface disposal systems.

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*With a single tile field or leaching bed this becomes impractical since sewage disposal facilities would be unavailable during resting periods. Modern design practice using dual tile fields, each less than the full size of a single tile field, offers potential solution to this problem.

Experimental evidence is inconsistent regarding the travel of microorganisms from sewage effluent through the soil. Much evidence indicates that the soil filters out most pathogens in the first 5-10 feet of travel, but other experiments indicated that significant quantities of bacteria were transported as much as several hundred feet through soils. While viruses appear to undergo a fate similar to bacteria, the behavior of the hepatitis virus has not been clarified because of laboratory analysis (culture) difficulties. Many chemicals are absorbed in the soil or taken up by plants, but others, excess nitrates in particular, are not removed and can contaminate groundwaters. If the absorption bed is underlaid with impervious strata, accumulating liquid ponds can erupt through the surface, and if creviced rock is too close to the absorption field, incompletely treated effluent can pass directly to groundwater supplies. Depending upon the mixing properties of the contaminated groundwater aquifers, such water reserves may become unsuitable for higher level uses such as drinking. Thus, geological surveys should be considered in determining the suitability of a location for soil disposal.

ECONOMIC AND ENVIRONMENTAL IMPACT IMPLICATIONS OF THE DIFFUSION OF INDIVIDUAL TREATMENT TECHNOLOGY

At sufficiently low densities (around 16 people per acre) individual waste treatment systems utilizing current practices can compete favorably with centralized systems on economic considerations alone. With available improvements in technology and practices, individual systems can be expected to become even more competitive. A MITRE-developed economic and environmental impact model for generating alternative future mixes of individual and central systems (based on variable assumptions about the speed with which improved technology will diffuse and the ultimate coverage it can attain) has been used to estimate the advantages of developing improved individual system technology and accelerating its acceptance and utilization. The results indicate that the present value of the cost advantage of a rapidly developed and widely utilized (5 years to introduce and another 5 years to half-maximal utilization in new individual home construction; ultimate maximum of 33 percent of new individual home construction) technology over the alternative of inaction in the individual systems area is about $3 billion. This savings potential is relative to a total (present value) cost of $31 to $36 billion for providing treatment to the new individual home population in the 1970-1989 period.

For the same comparison, a reduction in annual surface stream BOD loading of some (85 ± 40) thousand tons and an increase in groundwater recharge of about (1,000 ± 200) billion gallons per year could be expected if improved individual system technology were to be rapidly and widely introduced.

ADMINISTRATIVE CONSIDERATIONS

The prevalent pattern of ownership and operation of the individual system by the homeowner should be replaced by arrangements under which knowledgeable collective bodies (private, quasi-public, municipal or state) take over responsibility (and fund-raising authority) for the supervision of design and installation and the systematic inspection and maintenance of individual systems. The shift of the operational burden from individuals to collective groups can be a potent step in effecting the transfer of technological improvements and the widespread adherence to safe operating practices.

DEMONSTRATION PROGRAM

A coordinated approach which reflects technological, institutional, financial, regulatory, and codification facets is required if the full potential of individual systems is to be realized. A focusing and coordination of the diverse facets and interests is necessary to facilitate the needed transfer of technology. A technically-based demonstration program could serve as the focal point and the first step in the transfer from technological potential to actual practice.

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SECTION I
PROBLEM STATEMENT AND APPROACH

In many communities, individual home waste treatment systems can be considered as one alternative to centralized sewage collection and treatment systems. On the plus side, individual systems when properly designed and maintained, can provide treatment equivalent to many advanced waste treatment techniques at costs less than most centralized systems with secondary treatment. Individual treatment using sub-surface discharge recharges ground water supplies and prevents the loading of surface waters with nutrients and other oxygen-consuming substances. Individual treatment systems can change patterns of community growth by freeing developers from the necessity of building along existing or planned sewer lines.

On the minus side, individual treatment systems have had reputations of high failure rates which have resulted in such unpleasantries as back-up of sewage into homes, seepage of only partially treated malodorous liquids into lawns or drainage ditches and ultimately to surface waters, and contamination of ground waters. Individual systems require periodic maintenance by the homeowner or his agent, and this can be viewed as a nuisance when compared to distantly located centralized collection and treatment systems operated by trained personnel.

Individual systems, characterized by the septic-tank more than by any other device, are the subjects of more tradition, art, guesswork, and folklore than consistent scientific fact and competent engineering practice. Most septic tank failures probably result from improper design, installation, and maintenance rather than from any inherent flaw in the concept or gross misuse by homeowners.

The purpose of this report is to evaluate the potential effectiveness of individual home waste treatment systems and to estimate the cost implications of increased use of individual systems.

In order to evaluate potential effectiveness it is important to obtain a clear picture of the circumstances under which failures have occurred in the past. Accordingly, a review of previous research into septic tank system failures was conducted, and is summarized herein.

Economic factors which can govern the choice between individual and collective systems are reviewed. The results of several economic analyses of the problem are discussed. A MITRE-developed economic model is used to generate both the time stream and the total present value of future costs of sewage treatment on a national basis for projected new individual homes. Simultaneous consideration is given to individual and central systems for a variety of independently specified parameters such as the speed with which improved individual system technology could be introduced and implemented on a large scale, estimated ultimate utilization rate of individual system technology, investment costs and periodic expenses associated with individual systems, design populations and patterns of treatment for central systems, planning period, discounting rates, etc.

To the extent that individual treatment systems offer a cost-effective alternative to central systems, procedures should be devised for overcoming the poor image of such systems, including the pervasive septic tank-soil absorption system, and expanding their use. Accordingly, a coordinated approach to increasing the extent and rate of diffusion of improved new individual system technology is required. The basic thrust of this approach revolves about the creation of a soundly based demonstration program to develop and make widely available technical design, installation, and maintenance practices. This program must be conducted in a controllable and documentable technical environment with due consideration given to the interests of those parties who control the rate at which such a technology can be used. In the demonstration program, individual system alternatives considered should include conventional septic tank-soil absorption systems, modern modifications of such systems, aerobic systems (with and without subsoil disposal), and other technologies whose present potential indicates near-term economic and technical feasibility.

However, in such a technology diffusion program, technological aspects alone provide only the foundation. Of equal importance are the institutional, financial, regulatory, and codification aspects. For example, the potential use of Section 8 Construction Grant Funds for both construction and planning in support of the individual system alternative to sewage treatment requires examination. A major component of this aspect has to do with the existence of duly constituted collective agencies, recognized by the state, to provide design, inspection, maintenance, ownership, and rental capability. Such agencies are beginning to appear on the scene. They provide an interesting innovation in the social structure in response to a real need. Further investigation of other suitable organizational forms, including the utility concept, is warranted.

Codification of technical considerations and the creation of both appropriately revised model codes and legislation is another important component of the technology diffusion program.

Although this report concentrates on technological and economic issues, this is not to say that these other aspects have been overlooked. The social, institutional, and financial aspects of technology diffusion must be given proper consideration at the outset.

SECTION II

BACKGROUND

RECENT HISTORY OF INDIVIDUAL TREATMENT SYSTEMS

The demand for housing following World War II was reflected in the abrupt rise in new housing starts from a wartime level of 300,000 new units to 1 million units in 1946 and a steady rise to almost 2 million new units in 1950. While the cities had their share of the housing boom, the demand for low-tax, low-density areas for single-family dwellings was satisfied in many cases by a leapfrogging of housing developments beyond the range of existing water and sewer services. Homebuilders met these needs by resorting to the expedient of household wells and septic tank systems for an estimated 4 to 5 million homes between 1946 and 1950 alone. Between 1950 and 1960, $6.6 billion was expended for public sewerage systems, but little net gain was made in eliminating the septic tank and cesspools from congested areas. While some 10 million individual on-lot units were taken out of operation by the availability of new public sewers, the proliferation of new units was such that by 1960 some 21 million units were in use.*

The proportion of new individual homes using individual systems in 1970 is not a precisely known figure. The U.S. Public Health Service estimated that in 1967, 25 percent of new homes were being constructed with individual systems. Federal Housing Administration records indicate a 10-percent utilization in 1967 for individual housing units under FHA programs.

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*Kruse, C. W., "Our Nation's Water: Its Pollution Control and Management," in Pitts, J. N. and Metcalf, F. L., eds., Advances in Environmental Sciences, Vol. 1, Wiley-Interscience, N.Y., 1969.

The trends in waste handling services are depicted in Figure 1. It can be seen that about 70 percent of the population is currently served by sewers, and of these, about 92 percent are served by waste treatment facilities. The 30 percent of the population which is not served by sewers depend on some 15 to 17 million septic tanks and cesspool installations, and 5 to 10 million households use more primitive techniques such as privies or direct discharge to watercourses.*

The codes and regulations which governed the use of septic tank and cesspool systems in the post-World War II housing boom were generally administered by local health agencies which tended to be poorly staffed for such activities. As for the content of the codes, McGauhey and Winneberger noted:

> Over the years what was either known or presumed to be true concerning the design and construction of individual septic-tank systems was codified by state and federal health authorities in manuals of practice or in leaflets for use by the individual citizen or by the local jurisdiction.**

Little can be said about septic tank failure rates before World War II, because what records of reported failures that may have been kept were scattered throughout thousands of local municipal offices.

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*General Dynamics, Electric Boat Div., A Study of Flow Reduction and Treatment of Waste Water from Households, for the Federal Water Quality Administration, #11050 FKE 12/69, December 1969.

**McGauhey and Winneberger. Summary Report on Causes and Prevention of Failure of Septic-Tank Percolation Systems - 1963, University of California, Berkeley, Sanitary Engineering Research Laboratory Report, SERL No. 63-5.

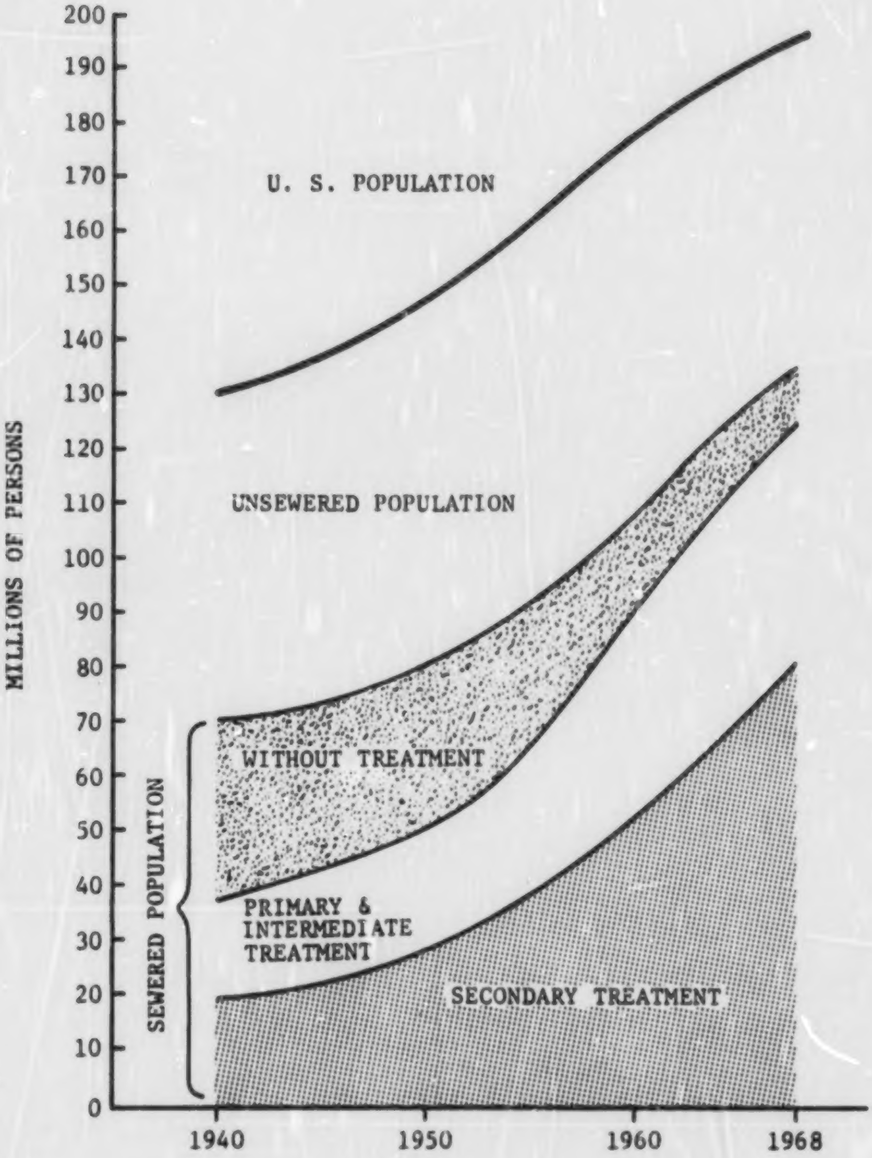

FIGURE 1

GROWTH OF PUBLIC WASTE HANDLING SERVICES

SOURCE: U.S. Dept. of the Interior, Federal Water Pollution Control Administration, "The Economics of Clean Water," Vol. 1, Detailed Analysis, March 1970, p. 75.

McGauhey and Winneberger further contended that it was the emergence of the Federal Housing Administration's responsibility for good construction techniques (because of their role of insurer of home loans) that brought to light previously unsuspected limitations of septic tank percolation systems.

> Failure of as many as one-third of the percolation systems in a single subdivision was recorded during the first 3 or 4 years after construction in many U. S. communities. In one case an entire subdivision of more than 1000 homes had to be repossessed, refinanced, and resold after septic-tank systems which failed wholesale had been rebuilt.*

Today, as mentioned, a significant proportion (10-25 percent) of new homes are built with septic tank-soil absorption systems despite the long history of previous failures. In many cases, septic tanks are still viewed as temporary expedients until central sewer systems can be constructed. The modes and the respective rates of septic tank failures are not known precisely, much less the "age specific" failure rates. Where properly installed and adequately maintained, septic tank systems are staunchly defended by their owners, who often refuse to have any part of public sewer systems. On the other hand, homeowners who have experienced septic tank failures show a strong preference against septic tank systems in their subsequent home purchases.

Against this backdrop of mixed performance, public health agencies tend to regard individual treatment systems as an acceptable waste treatment alternative only if public sewer service cannot be obtained. The U.S. Department of Agriculture's Economic Research Service stated that "Use of septic tanks and cesspools, except under the most favorable conditions, should be considered a temporary stopgap until public facilities can be developed."

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*Ibid.

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*USDA, Economic Research Service, Status of Water and Sewage Facilities in Communities Without Public Systems, Agricultural Economic Report No. 143, October 1968.

SECTION III

TECHNICAL CONSIDERATIONS

THE NATURE OF DOMESTIC SEWAGE

Sewage from individual homes is indeed a complex commodity. It consists of all manner of things that go down drains or that are flushed down toilets. As one might expect, the composition of sewage varies from day to day, even from hour to hour, and also from house to house. On the average, domestic sewage consists of about 99.9 percent water (weight), 0.02- to 0.03-percent suspended solids, and other soluble organic and inorganic substances.* Sewage also contains bacteria, viruses, and other microorganisms from the digestive tract, respiratory tract, and skin, which make their way to toilets and drains.

In a single-family house, the laundry and kitchen each account for 10 percent of the wastewater volume, while the bathtub/shower/handwash-basins account for about 40 percent, and the toilets account for the remaining 40 percent.** The organic chemical content of domestic sewage comes primarily from human wastes, soaps, and food wastes (especially in homes where a garbage disposal is used).

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*Pelczar, M. J. and Reid, R. D. Microbiology, 2nd ed., McGraw-Hill Book Co., New York, 1965, p. 512.

**Laak, R. "Design Factors for Seepage Beds," Proceedings of Sewage Treatment in Small Towns and Rural Areas, A Conference Addressed Primarily to the State of Vermont, Thayer School of Engineering, Dartmouth College, Hanover, New Hampshire, March 3, 1971, Chapter II, p. 3.

One measure of the "strength" of the sewage is directly related to the amount of organic material present. This is measured as a biochemical oxygen demand (BOD). The BOD is the total amount of oxygen which is utilized by microorganisms in digesting the wastes, i.e., by converting the wastes to more-or-less fully oxidized end products. This type of end product is called stabilized sewage. When sewage is only partially broken down, i.e., not fully stabilized, it will later require more oxygen from the environment to complete the oxidation process. The most common BOD measurement is accomplished by diluting a sample of sewage with water containing a known amount of dissolved oxygen and incubating the mixture in a tightly sealed bottle for five days at 20°C (68°F). The amount of oxygen used during the five days is determined by measuring the amount remaining and subtracting it from the starting amount. This particular type of BOD determination is referred to as a BOD_5, and it amounts to about 80 percent of the oxygen used in the oxidation process which, of course, may take more than five days. Typical values of BOD for raw domestic sewage are several hundreds of parts per million, ppm (which is roughly equivalent to milligrams per liter, mg/l).

SEPTIC AND AEROBIC TANKS

A septic tank is a watertight tank which is designed to slow down the movement of raw sewage and wastes passing through so that solids can separate or settle out and be broken down by liquification and bacterial action. It does not purify the sewage, eliminate odors, or destroy all solid matter.* Septic tanks can be made of metal, built-in-place of masonry or poured concrete, precast in concrete, or made of other suitable materials. In general, very few system failures have been attributed to failure of the tank *per se*. Since the tank has no moving parts, about all that could go wrong with the tank itself is the springing of a gas or liquid leak.

Not all of the solids entering the tank, however, are broken down into liquids or gases. Some settle out in a sludge layer on the bottom or rise to the top in a layer of scum (primarily undigested fats and oils). These are illustrated in Figure 2. Baffles and other physical design arrangements are often provided to improve the hydraulic flow characteristics, and to prevent influent from short-circuiting the tank and exiting the tank directly in the effluent. The longer the influent is detained in the tank, the greater the degree of settling out of solids, and the cleaner the effluent. Thus, larger tanks should give better effluent than smaller ones of the same design. As the sludge accumulates, the effective tank capacity will decrease, and

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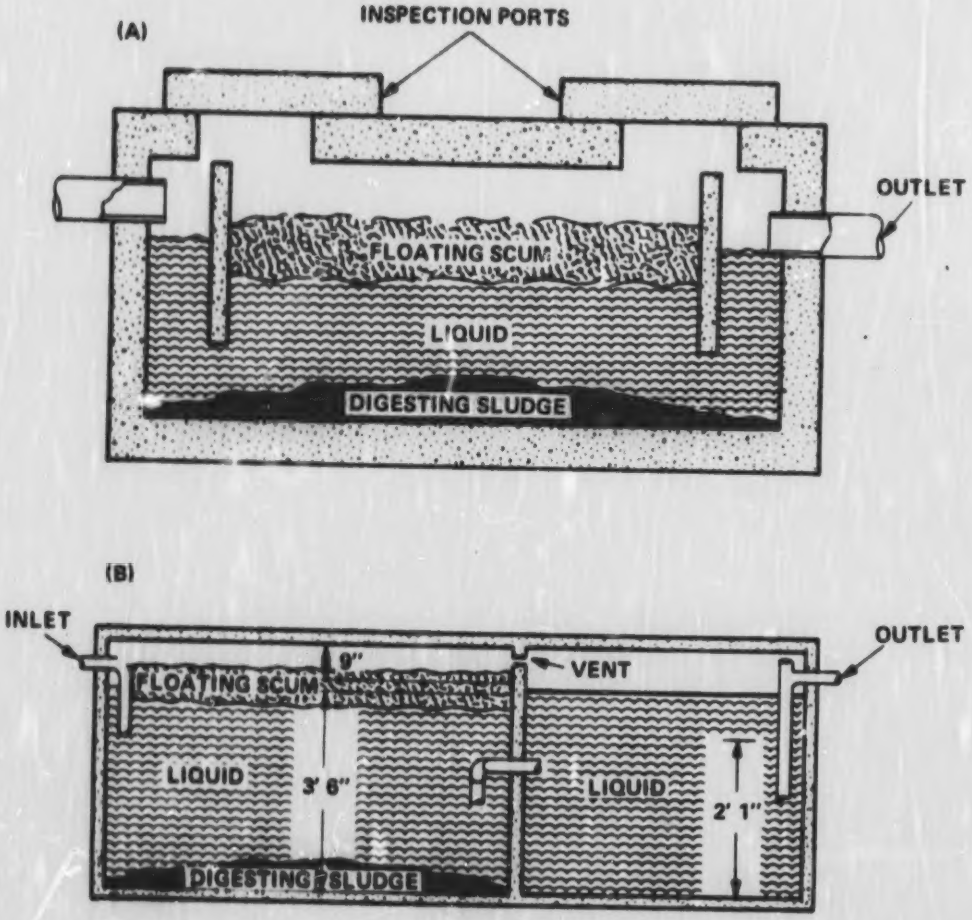
*Salvato, J. A., Jr. *Environmental Sanitation*, Wiley, New York, 1958, p. 206.


(A)
INSPECTION PORTS
OUTLET
FLOATING SCUM
LIQUID
DIGESTING SLUDGE
(B)
INLET
OUTLET
9"
VENT
FLOATING SCUM
LIQUID
3' 6"
LIQUID
2' 1"
DIGESTING SLUDGE

CONSTRUCTION MATERIALS: CONCRETE VITRIFIED CLAY, CONCRETE BLOCKS, BURNED BRICKS, STEEL AND OTHER MATERIALS

SOURCES:
(A) BAILEY, BENOIT, ET AL.
(B) MANUAL OF SEPTIC TANK PRACTICE, U. S. PUBLIC HEALTH SERVICE, 1967.

FIGURE 2
SEPTIC TANK: TWO DESIGNS AND CONSTRUCTION MATERIALS

when the fluid capacity is reduced sufficiently, the water will flow through rapidly enough to pull some of the sludge with it ("sludge wasting") and effectively defeat the purpose of the tank. Thus, while the tanks generally do not fail structurally, failure to have the tanks inspected regularly for sludge buildup and pumped out as required can lead to failures downstream in the absorption system. Recommended tolerances on sludge accumulation are given in several references on septic tanks[*][‡], and the details are not of major concern here.

In addition to the septic tank, aerobic treatment tanks have been available for several years. Septic tanks are so named because the breakdown of organic solids is accomplished by bacteria which function in the absence of oxygen (i.e., sepsis). In aerobic tanks, the fluids are oxygenated by a mechanical aeration pump, and degradation of the solids is accomplished by bacteria, protozoa, and other microorganisms which utilize oxygen (i.e., aerobes).

Based upon presently available technical evidence, it is not at all clear which type of unit is inherently superior in removing suspended solids and reducing the oxygen demand of the household wastes. The work of Winneberger et al., summarized and reproduced as Table I, indicated to those investigators that there was no significant ($P > .05$) difference between septic and aerobic tank performance as regards removal of biologically or chemically oxygen demanding constituents of waste waters, though the septic tank was

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[*] U.S. Department of HEW, *Manual of Septic-Tank Practice*, 1967.

[‡] J. A. Salvato, *op. cit.*

TABLE I

ONE COMPARISON OF SEPTIC AND AEROBIC TANK PERFORMANCE*

PARAMETER	Aerobic Unit Effluent		Septic Tank Effluent		Raw Sewage Influent	
	mean	std. dev.	mean	std. dev.	mean	std. dev.
BOD mg/1[γ]	81.0	25.9	73.7	10.8	153.2	66.8
COD mg/1[δ]	143.5	39.1	152.0	29.2	305.4	111.8
SS mg/1[ε]	75.4	θ	50.6	θ	~180[λ]	θ

[γ] Biochemical oxygen demand.

[δ] Chemical oxygen demand.

[ε] Suspended solids.

[θ] Not reported.

[λ] Estimated from information in text.

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*Winneberger, J. H., et al. Biological Aspects of Failure of Septic Tank Percolation Systems, Sanitary Engineering Research Laboratory Report, University of California, Berkeley, August 31, 1960, pp. 77-81.

significantly more stable in its performance (i.e., septics responded better to pulse loads than did aerobics). The septic tanks also appeared to remove more suspended solids than did the aerobic tanks, though the authors remarked that there was evidence of short-circuiting in the aerobic tank.

Bernhart found quite the opposite behavior from his field investigations which indicated superior aerobic tank performance as regards removal of both oxygen demanding substances and suspended solids, Table II. Bernhart also argued that aerobic tanks are more effective at reducing the numbers of coliform bacteria (a group of bacteria which live in the gut of mammals and are associated with fecal waste) because the aerobic microorganisms include protozoa which feed on coliform bacteria.*

In a recent research project report, Schad reported aerobic tank performance expectations as follows: biochemical oxygen demand (BOD) reductions of 75 - 90 percent and total suspended solids (TSS) reduction of 75 - 90 percent, based on test results he had received from independent testing consultants. By comparison, Schad offered figures for BOD and TSS reductions of 30 - 50 percent for septic tanks. Schad also stated that aerobic tanks typically discharge fluids with concentrations of coliform bacteria around 10^5 per 100

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*Bernhart, Alfred P., "Waste Water Units for Individual Buildings and Houses," Engineering Journal (Canada), pp. 19-25, July 1964.

TABLE II

A SECOND COMPARISON OF SEPTIC AND AEROBIC TANK PERFORMANCE*

	Septic Tank with Anaerobic Seepage Bed		Septic Tank with Aerobic Seepage Bed		Aerobic Tank with Aerobic Seepage Bed	
	SS (ppm)	BOD (ppm)	SS (ppm)	BOD (ppm)	SS (ppm)	BOD (ppm)
Raw Waste Water	280	300	210	290	280	300
Tank Effluent	110	260	80	240	40	10
Seepage Bed Effluent	80	200	40	4	10	1

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*Ibid.

milliliters (MPN)*, whereas septic tank effluents contain around 10^7 per 100 milliliters (MPN).**

The above details about septic and aerobic tanks illustrate quite forcefully that, even among respected and highly trained disposal system experts, there exist divergent and opposing evaluations even when these are based on experimental evidence and/or field data. Another general truth in this field is also supported by the above evidence, namely that the validity and comparability of performance data may be strongly influenced by peculiarities of design, installation, and usage patterns of individual units (along these lines one may speculate that the short-circuiting which Winneberger's group noted in their aerobic tanks may have been the cause of their poor performance as compared to the other investigators observations).

THE SOIL ABSORPTION SYSTEM

The most fragile and most expensive part of the individual home waste treatment system is the soil absorption system which lies downstream of the septic or aerobic tank. The liquid part of the tank effluent can only move three ways: down (through the soil and possibly down to ground waters), laterally (travelling through the soil or ground water aquifers), or up (by ponding in impervious soil until it errupts through the surface, or by direct diffusion through and evaporation from soil or by being taken up into and evaporated by plants). Tank effluents carry all manner of microbes (bacteria, viruses, protozoa, etc.) and organic and inorganic compounds in dissolved, colloidal, and suspended states. Depending on the ultimate use of the effluents, these constituents may be regarded as improving or degrading water quality. The soil through which these fluids pass acts as a physical filter, chemical reactor, and biological transformer in further processing the tank effluents and modifying its quality attributes. Proper operation of the soil system occurs when the water that goes up, across, and down leaves the immediate zone of the soil system with locally acceptable values of its physical, chemical, and biological quality parameters. The mechanisms by means of which all this is accomplished are far from being completely described, though what is known about them already fills many volumes. Painter conducted a detailed analysis of raw sewage and percolating filter effluent, and he was able to assign about 75 percent of the organic carbon in raw sewage and 79 percent in settled sewage to definite chemical groups (e.g., carbohydrates, amino acids, etc.). After passing through the filter, only about 30 percent of the organic carbon could be so assigned.* This means that typical sewage is not well described to begin with, and even less well described after what amounts to secondary treatment. Organic compounds are transformed into other compounds, usually greater in number and smaller in molecular weight.

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*MPN = most probable number, a statistical inference about the number of organisms based on results of replicated macroscopic tests.

**Schad, T. O. Sewage Treatment in Rural Areas of Vermont, Bachelor of Engineering Project Report (thesis), Dartmouth College, Hanover, N.H., June 1971, pp. 10-21.

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*Painter, H. A. "Composition of Sewage and Sewage Effluents," Journal of the Institute of Sewage Purification, Part 4, p. 302, 1961, as cited in McGauhey, P. H., and R. B. Krone, Soil Mantle as a Wastewater Treatment System, SERL Report No. 67-11, Sanitary Engineering Research Laboratory, University of California, Berkeley, December 1967, p. 50.

The final word on septic tank and soil biodegradation mechansims is far from being uttered, so that the total picture is not only complex, but understood only in elementary fashion.

The soil absorption system may take many forms: a long narrow trench, a wide shallow bed, a deep pit, or combinations of these, all underground or contained within a specially built mound above the ground. Tank effluent is conveyed to the absorption system by means of pipes from the tank which may pass through a distribution box, or which may connect directly with perforated pipe in the trenches and beds or directly to the subsoil/seepage pit. The effluent seeps from the pipes across the soil-water interface and into the soil. More often than not it is at the interface that the trouble begins. The flow is illustrated schematically in Figure 3, where it can be seen that en route from house to soil, the flow of fluids can be completely blocked at any point.

Prior to about 1960, hardly anybody would have drawn the soil-water interface as a separate entity in the flow diagram. Its presence is testimony of the realization that what governs the long-term ability of an initially absorptive soil to continue to receive waste effluent

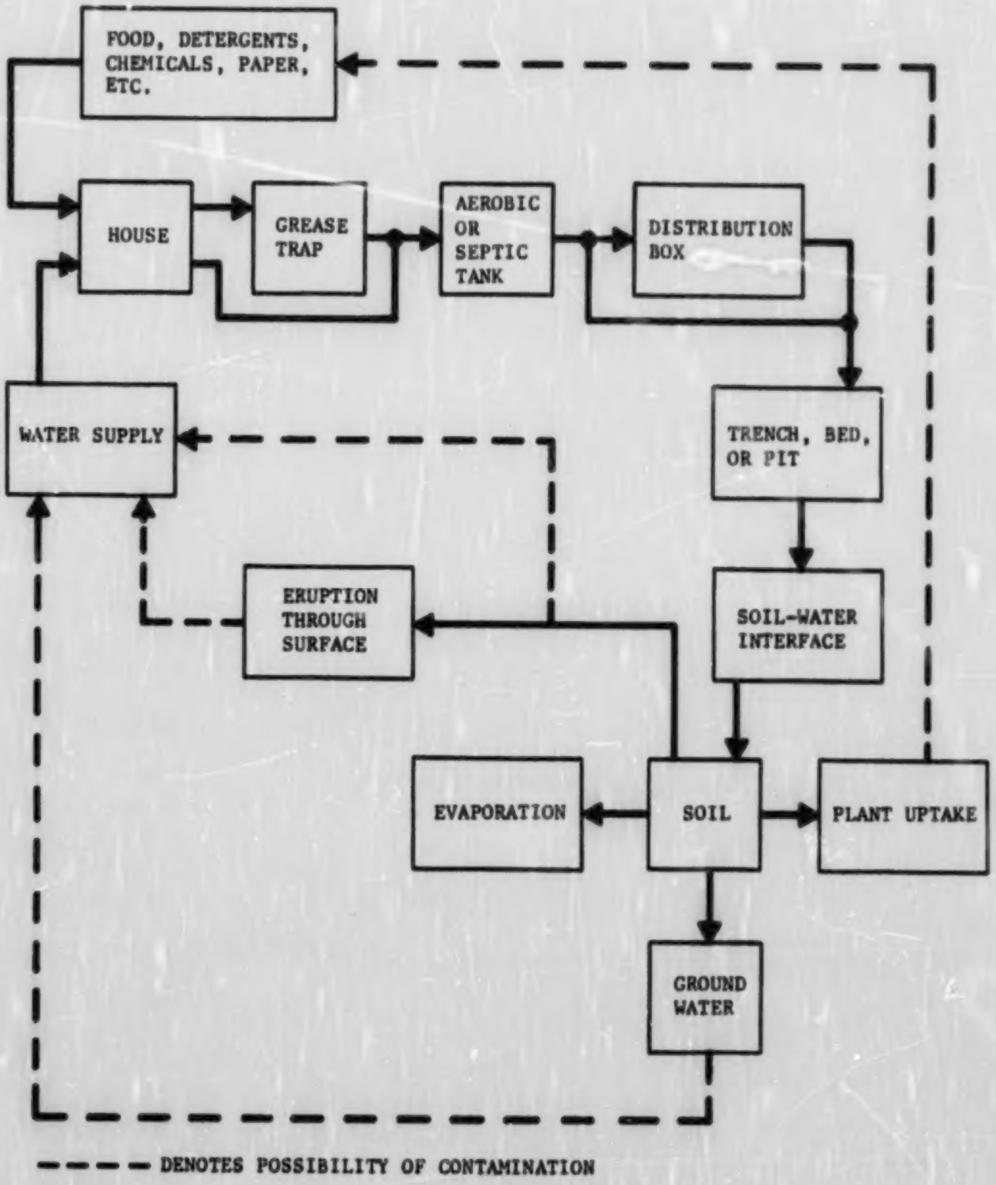
FOOD, DETERGENTS, CHEMICALS, PAPER, ETC.
HOUSE
GREASE TRAP
AEROBIC OR SEPTIC TANK
DISTRIBUTION BOX
WATER SUPPLY
TRENCH, BED, OR PIT
ERUPTION THROUGH SURFACE
SOIL-WATER INTERFACE
EVAPORATION
SOIL
PLANT UPTAKE
GROUND WATER
DENOTES POSSIBILITY OF CONTAMINATION

FIGURE 3

COMMODITY FLOW IN AN INDIVIDUAL SUBSURFACE WASTE TREATMENT SYSTEM is the facility with which the liquid can pass through a clogging layer which develops with time at the interface. This may be termed the infiltrative capacity of the soil as contrasted with the percolative capacity which is the rate at which water moves through the soil once it has passed the interface.*

The known mechanisms of clogging are reviewed in detail in Appendix A. A more compact discussion of clogging is given in the next few paragraphs. The mechanisms have, for the most part, been elucidated in experiments which lasted less than a year, though the failures of septic tank-soil absorption systems in general take many years to occur. Though the relationships between the short-term mechanisms and long-term failures have not been clearly established, it would seem prudent to avoid aggravating long-term failure possibilities by minimizing the influence of short-term failure mechanisms.

SOIL CLOGGING MECHANISMS

Though physical forces and purely chemical (as opposed to biochemical) reactions may lead to alterations in soil pore size and infiltration rate, clogging appears to be predominantly attributable to the accumulation of suspended matter from the wastewater, bacterial cells, and products of microbial activity which collect and eventually block pores. The rates of addition and/or production versus rates of degradation of these clogging materials appear critical. Some clogging occurs under both aerobic and anaerobic conditions but most severe clogging appears when oxygen is absent or present in only very low concentrations.

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*Note: present conventional criteria for suitability of soils for individual soil absorption system usage depend upon the percolation test rather than on any test of infiltrative capacity. This is an area requiring detailed technical exploration with significant probable payoff. Another such area is the development of accelerated life testing techniques for soil absorption systems.

Physical factors which may contribute to soil clogging in some cases include compaction of soil by heavy loads; smearing of soil surfaces by excavating equipment; and changes in particle distribution, including migration of fine particles by soil vibration during site preparation and washing down of fines initially perched on larger particles. Many current installation practices neglect these factors with consequent physical damage to soil absorption systems. Chemical factors include aggregate dispersion by sodium ion; iron or phosphate coating of soil particles; and chemical precipitates such as carbonates or sulfates of certain metals (e.g., Al, Fe, Cd) or alkaline earth materials (Ca, Ba, Mg).

It seems apparent that suspended matter, both organic and inorganic, is an important factor in initial decreases in infiltration rate in most systems. Particle size and initial soil pore size are both involved in this aspect of clogging, with large solids apparently less capable than smaller solids of clogging fine porous media, but more capable of clogging coarse porous media by bridging the large pores through which finer suspended matter easily flows.

The addition of organic matter in the applied wastewater stimulates the growth of microorganisms, particularly bacteria. Those microbes may reach high numbers and may behave as particulates, decreasing pore size and interfering with passage of the wastewater. These organisms also consume oxygen and produce breakdown products as they degrade added organic material.

When infiltration rates decrease due to the above factors, and the system is not given sufficient rest for drainage and restoration of soil pore oxygen, oxygen levels in the soil will decrease over time. At decreased oxygen levels, degrading processes proceed at lower rates and, in some cases, apparently cease. This may lead to the accumulation of microbial products, eventually producing severe clogging.

Polysaccharides, and particularly, polyuronides, which are constituents of sticky gums and which are degraded only under very aerobic conditions, are the most likely substances responsible for severe and prolonged clogging. These carbohydrates, notable for their role in aggregate stabilization, apparently help bind clay particles together as long as there are surface sites available for such binding, and in this state are resistant to degradation. When surface sites are exhausted, newly produced polysaccharides are rapidly degraded if oxygen is available but accumulate as part of sticky gums if oxygen tension is low. Polyuronides appear to be particularly resistant to degradation in the soil, probably due to complexing with some other organic material. These substances have been shown to accumulate in soil coincident with decreased infiltration rates.

Total organic matter in soil samples has also shown positive correlation with changes in infiltration rate, and it is likely that other organic substances which tend to resist degradation (e.g., lignins, tannins, waxes) also interfere with infiltration of wastewater throughout the process. Dead microbial cells, decomposed only slowly in anaerobic atmospheres, probably are also a factor. It should be noted that aerobic tanks provide an effluent with higher dissolved oxygen content than septic tank effluents. However, it remains to be determined if the initial aeration of effluent carries very far into the soil interface down the length of a tile field. The solubility of oxygen in fresh water is around 10 mg/l.* If the effluent has a BOD (and/or COD) higher than the dissolved oxygen level (recall that aerobic tank effluents usually exceed a BOD of 10 mg/l), anaerobic conditions will set in when the dissolved oxygen is used up unless extra oxygen is supplied by diffusion through the soil. Direct aeration of the full length of the tile field also warrants further investigation.

When the soil atmosphere becomes anaerobic, ferrous sulfide is usually produced spontaneously by the reaction of ferrous and sulfide ions, separately produced by anaerobic microorganisms which use sulfate and ferric ions as electron acceptors in their metabolic processes. The source of the iron and sulfur may be the wastewater or the soil or both. The FeS particles are colloidal and could contribute to severe clogging in some cases, but their presence is generally accepted more as an indicator of the anaerobic conditions which lead to clogging rather than a cause in themselves.

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*See, for example, Babbitt, H. E. and E. R. Baumann. Sewerage and Sewage Treatment, John Wiley and Sons, Inc., New York, 1967, p. 345.

SOIL CLOGGING MECHANICS

As discussed in Appendix A, soils subjected to continuous inundation with fresh water exhibit: (a) an initial decline in infiltration rate, followed by (b) a recovery, which is then followed by (c) a gradual die-away of infiltration rate to an equilibrium rate which is generally quite small compared to the initial rates in phases (a) or (b). The gradual die-away appears to reach the same equilibrium value whether sterile water or sewage is the inundate though it is accelerated with sewage to the point that it masks phase (b). The die-off does not occur when sterile water inundates sterile soil [phases (a) and (b) still do occur, however]. This indicates that phases (a) and (b) involve mainly physical and chemical mechanisms, whereas phase (c) reflects biological activities; further, phase (c) can be brought about by soil microbes as well as microbes and nutrients in the sewage. Phase (c) has been shown to be a characteristic of the clogging layer at the interface and it generally is accompanied by anaerobic conditions, whereas the soil percolation qualities evidenced in phases (a) and (b) are characteristic of the bulk soil, and may proceed in the presence of sufficient soil oxygen.

When no new fluids are spread and the inundate is fully infiltered, the clogging layer dries and breaks up under aerobic conditions, and the infiltrative capacity is restored nearly to values which originally prevailed at the start of the die-off. Thus, clogging can be reversed by periodically resting the soil.

In any absorption system where the depth is large with respect to the width, absorption takes place mainly through the sidewalls rather than through the bottom area. Examples are narrow absorption trenches and seepage pits. As the effluent infiltrates into the sidewalks and the depth of effluent decreases, the uppermost zones are rested first and longest, while the lowest zones and the bottom are rested last and least. If new effluent is applied before the old effluent is fully absorbed and before the bottom zones have fully regained their infiltrative capacity, the lower levels of the trench or pit will lose their ability to pass fluids, and infiltration can occur only through the higher zones. Ponding of effluent will occur as soon as the effluent recedes down to the fully clogged zones. As the next load of effluent is applied, the next higher zone can then become fully clogged, and so on up the walls until the whole absorption system will have failed. This is the "creeping failure" mode which was identified by investigators at the Sanitary Engineering Research Laboratory of the University of California.* Creeping failure obviously can operate for a long time before the absorption field fails completely, and this could account for many of the instances of failure of septic tank-soil absorption systems within a few years of start-up. By that time, of course, the builder or septic tank contractor can disclaim any liability for the failure, and the homeowner is left holding the bag.

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*See, for example, McGauhey, P. H., and J. H. Winneberger. A Study of Preventing Failure of Septic-Tank Percolation Systems, Final Report, SERL Report No. 65-17, Sanitary Engineering Research Laboratory, University of California, Berkeley, 31 October 1965, p. 9.

THE VULNERABLE ROLE OF THE VENERABLE SOIL PERCOLATION TEST

Henry Ryon is generally credited with having developed the percolation test as a tool for assessing the ability of a soil to receive wastewaters and to function properly without failure. He developed the test around 1926 through empirical studies of relationships between actual "premature" (less than 20 years) cesspool and absorption trench failures and the rate with which clear water could infilter the surfaces of a hole dug in that soil and saturated with water before the actual test was begun. Ryon's criteria and methods have been accepted, with minor modifications which vary from jurisdiction to jurisdiction, on an international basis as the standard indicator of the suitability of the soil for surface and subsurface disposal of sewage. (Ask any real estate salesman in a sparsely populated area about the suitability of a plot for septic tanks, and he will tell you that "The soil perc's real well here...no trouble at all!)

Most investigators would agree, since at least the early 60s, that there is a big difference between the initial ability of a soil (even one saturated overnight) to receive clear water and the long-term ability of the soil to receive wastewater. McGauhey and Winneberger* advanced the concept that the long-term capability of the soil to receive wastewater [i.e., phase (c) of the infiltration rate vs. time curve] is a function of the clogging mat of organic material which builds up at the interface rather than of the soil itself. Bearing in mind the series flow conditions illustrated in Figure 3, it would appear that the major value of tests based on Ryon's method should be to ensure that the percolative capacity of the bulk soil will at least exceed the expected long-term minimum value of the infiltration rate.

McGauhey and Winneberger's "Most Conservative" approach to absorption field design was based on a value of 0.03 ft./day (equivalent to a "percolation" rate of 4000 minutes per inch, or 67 times the normally acceptable maximum percolation rate for soil absorption systems!).** They indicated that this value is applicable for soils "from the smallest particle size that has a long-term percolative capacity of at least 0.03 ft./day up to those with an effective size of 0.1 mm" under conditions of cyclic loading (no more frequently than daily) and yearly alternation with another absorption field to provide a long-term rest.***

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*Op. cit.

**The loading value of 0.03 ft./day is equivalent to about ¼ of a gallon per square foot per day, or four square feet of absorption surface for each gallon of effluent.

***McGauhey and Winneberger, op. cit., pp. 28-29.

An example illustrative of the two different approaches would be the required absorption system size for a family of 5 people living in a 3-bedroom house where the percolation rate was 10 minutes per inch and absorption trenches were to be dug 2 feet wide and three feet in depth. The Public Health Service's Manual of Septic Tank Practice (1967 Edition) indicates a requirement of 165 ft^2 of trench bottom area per bedroom for a 10 min/in. percolation rate, or $(165 \times 3)/2 \approx 250$ lineal feet. McGauhey and Winneberger's "Most Conservative" criterion of 0.03 ft/day, or 4 $ft.^2$ per gallon, translates to a requirement of 1500 ft^2 of absorption surface at an assumed wastewater production of 75 gallons per capita per day (gpcd). This requires 250 lineal feet of trench 3 feet deep since both sidewalls are useable. (Note that the percolation-test-based design criteria concentrate on the trench bottom area, while McGauhey and Winneberger technique depends on the assumption that the bottom will be clogged beyond usefulness and that absorption occurs through the sidewalls). Had the percolation rate been 60 minutes per inch, a trench twice as long (500 ft.) would have been called for by the Manual of Septic-Tank Practice criteria, and this would have been more than adequate according to the "Most Conservative" criterion. If the percolation rate had been 3 minutes per inch, however, the required trench length would have been only 150 feet, which would provide only 60 percent of sidewall area called for by the "Most Conservative" criterion. All other things being equal, creeping failure could occur in the latter instance, even though the Manual of Septic-Tank Practice directions would have been followed to the letter!

In addition to the questions raised by the preceding discussion, the percolation test has been faulted by many authors for a variety of other reasons. Among them:

1. Even when the soil is prepared by overnight saturation of the test hole, the percolation rate is usually sensitive to the bulk soil moisture, and this varies seasonally in many areas. Thus, soil that doesn't "perc" well after the spring thaw might perc beautifully during summer drought.
2. Percolation rates are sensitive to the depth to which the hole is filled during the saturation preconditioning.
3. It is not at all unusual for measured percolation rates to vary by an order of magnitude when measured by different individuals using identical standard techniques. In an unpublished report, Winneberger reported measurements that ranged from 2 to 259 min./in. in a 0.2-acre prospective absorption field in which sets of three test holes were drilled in nine locations. One of the three holes was used by a different testing company in each of the nine locations. Average percolation rates (and ranges) over the nine locations were 22.06 (2 to 130), 53.1 (15 to 118), and 113.4 (24 to 259) for the three companies, respectively.*

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*Winneberger, J. H. The Percolation Test, A Blunt Tool at Best, Unpublished Report.

4. As shown implicitly in the design example, above, most manuals and codes which are based on the percolation test, specify bottom area requirements, whereas the sidewalls probably make the major contribution to the absorption in trenches.
5. More important than the percolative capacity of the soil, for almost any soil that will accept effluent and drain when effluent is no longer applied, is the requirement that borings be made to ensure that the underlying geological structure and water table depth are compatible with the absorption system design. The underlying geological structure is important, because effluent from the soil absorption system must be prevented from either reaching ground or surface waters before the objectionable impurities are removed or from ponding over impervious lower layers until the accumulated fluid breaks through the surface to present a health hazard.

The effects of water pollution from domestic wastes and the fate of bacteria, viruses, and chemicals in soil and groundwater are discussed in the following sections.

EFFECTS OF WATER POLLUTION FROM DOMESTIC WASTES

The original impetus to abatement of water pollution by domestic wastes arose out of a concern for human health. The transmission of water-borne diseases by bacteria and viruses in water supplies downstream from waste disposal points was the primary factor involved. Around 1880, water-treatment practices lacked positive barriers against bacterial pathogens and almost as many people died of typhoid then as are killed today in automobile accidents. The early 20th century introduction of chlorination contributed to the reduction of typhoid fever death rates by half. The average number of waterborne disease outbreaks in the United States from 1938-1960 has fallen, as indicated below.*

Period	Outbreaks	Cases Per Outbreak
1930 - 1940	45	583
1941 - 1945	39	201
1948 - 1950	23	121
1951 - 1955	8	139
1956 - 1960	7	121

Although occurrences of adverse health effects traceable to waterborne bacterial and viral pathogens have decreased, prospects of increased reuse of water by humans intensifies the need to know more about enteric viruses (those which occur in the gastro-intestinal tract). Untreated ground water has been the most frequent cause of recent outbreaks of gastro-enteritis and diarrhea; e.g., the waterborne epidemic of Salmonella typhimurium during May and June 1965 at Riverside, California, which involved 18,000 persons.* Viral infectious hepatitis can be transmitted by water routes, although this is rare. It has been shown that free residual chlorination effectively inactivates many enteric viruses. However, it is difficult to maintain free chlorine in heavily polluted water or sewage, since the many substances present combine with free chlorine. Combined chlorine when properly applied is effective against bacteria but not against viruses, except at prohibitively expensive levels.

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*Kruse, C. W., quoting Weible, et al., in Advance in Environmental Science, Pitts and Metcalf (Eds.), John Wiley-Interscience, 1969.

These considerations apply to central systems (sewers plus sewage treatment plants) as well as individual units. It is common practice, for example, to discharge untreated sewage along with runoff into surface waters in combined sanitary and runoff sewer systems when peak loads from storms exceed the handling capacities of treatment plants. Nor is it uncommon to bypass treatment plants during periods of malfunction or maintenance shutdown. As long as the sewers continue to accept his wastes, central system malfunctions are much less visible to the individual homeowner than back-ups from a plugged-up on-site system.

The long-term impact on human health of a variety of largely unidentified, often low-concentration, chemical compounds that enter sources of water supply, some from domestic wastes, is another major area of concern. At present levels of exposure, such water pollutants do not seem likely to have significant acute effects on health. However, nitrates, which can cause methemoglobinemia and deaths in infants, are not in this category. The chronic effects of continual low-level exposure to organic carcinogens and other substances is a less well defined area. Utilization of ground water basins for water treatment and dilution and movement of viruses in ground water are two areas in which data are extremely limited.* These latter two areas are closely linked with possible extensive use of individual waste disposal systems.

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*Kruse, op. cit.

BACTERIA AND CHEMICALS IN SOIL SYSTEMS AND GROUND WATER

Changes in water quality of pretreated sewage applied to soil systems can be partially described by the fate of bacteria, viruses, and chemicals as they move through soil systems and ground waters. Beneficial recharge of ground waters by individual systems is accompanied by the adverse effect of potential pollution of the ground water. It is known that soils remove bacteria and viruses by physical percolation. Particles are physically removed and ions and chemicals undergo ion exchange and biological degradation. The result of biological degradation may be stable ions found in ground water such as nitrates, sulfates, phosphates, and carbonates. Under conditions that are not clearly defined, soils remove chromate ions, phenols, and other compounds, yet under other conditions these compounds have reached ground water and traveled many miles.

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*American Chemical Society, Cleaning Our Environment, The Chemical Basis for Action, Washington, D.C., 1969.

Ground water supplies are becoming increasingly important. The Water Resources Council* indicates that in eleven of the twenty regions of the nation, there are moderate to severe problems of ground water storage depletion. Ground water aquifers supply 22 percent of the nation's withdrawal use of water and provide the base flow of streams, which in some regions provides a continuity of discharge they would not otherwise possess. The annual national investment in about half a million water wells comes to about half a billion dollars, indicating the importance of ground water resources. It has been estimated that total ground water storage greatly exceeds the volume of all five Great Lakes and that the usable portion is 150 times the amount of water used in the United States in 1965. Figure 4 identifies major areas of potential ground water development. As the Water Resources Council states:

> More effective development and management of the Nation's ground water potential offers considerable promise for fully utilizing our available water supply. The occurrence, movement and replenishment of subsurface waters is not as fully understood as surface waters. With time and adequate research, significant quantities of additional subsurface water in the Nation's water budget can be developed for use.**

This potential is to be contrasted with our state of knowledge in the area of ground water quality management. Loucks comments:

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*The Nation's Water Resources, the Water Resources Council, Washington, D.C., 1968.

**Ibid.

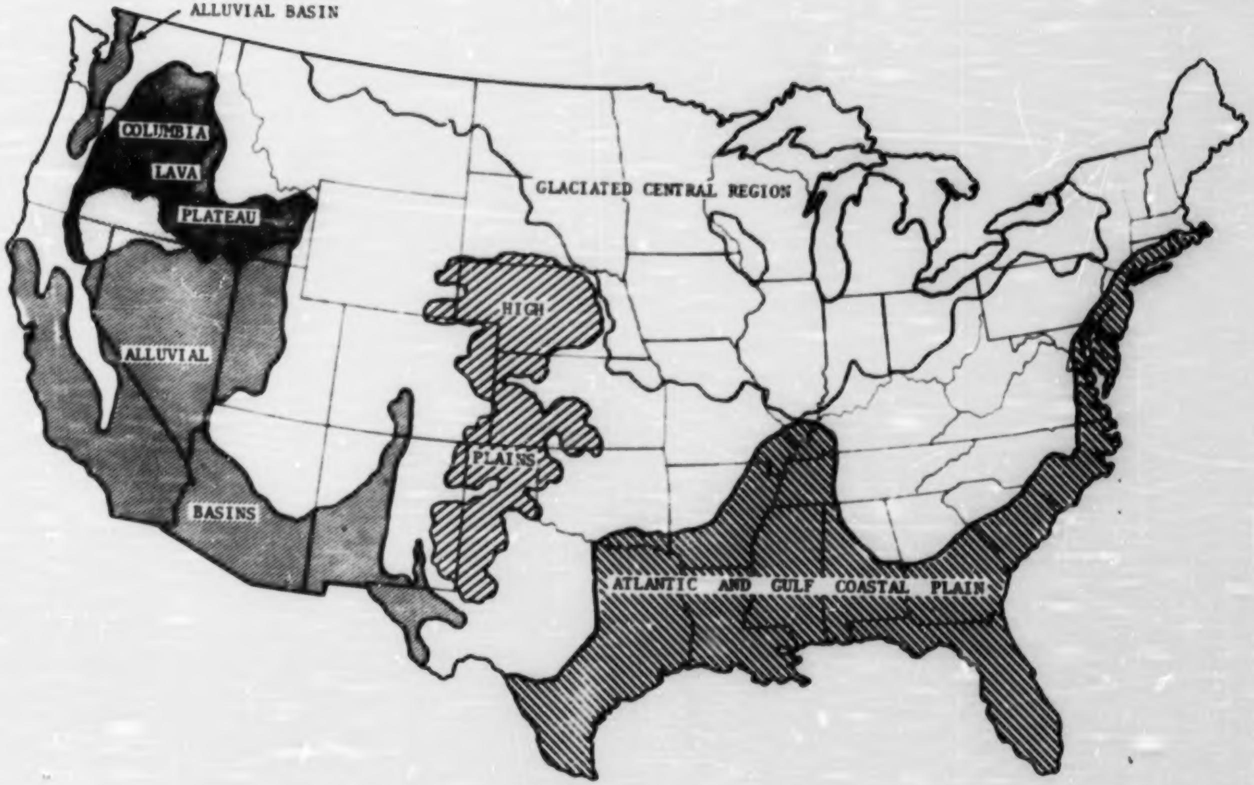
ALLUVIAL BASIN
COLUMBIA
LAVA
PLATEAU
GLACIATED CENTRAL REGION
ALLUVIAL
BASINS
HIGH
PLAINS
ATLANTIC AND GULF COASTAL PLAIN

FIGURE 4

MAJOR AREAS OF POTENTIAL GROUNDWATER DEVELOPMENT

> There is a need to manage ground water quality as well as surface water quality. Numerous wastes are discharged directly into the ground water supplied. We know little about the waste assimilative capacity of ground water quality. Models exist for the conjunctive use of surface and ground water supplies, but none to my knowledge exist for the conjunctive management for both surface and ground water quality.*

The ability of the soils to treat and transport substances traceable to domestic wastewaters, and their coupling to ground water reserves, is an important area requiring a good deal more attention.

Winneberger, who has been extensively involved in both academic research on properties of soil treatment systems and is currently practicing as a consulting engineer, believes that individual treatment systems, especially septic tanks, utilizing properly designed soil treatment and disposal systems present essentially no problem of mineral, viral, or bacterial ground water pollution.** His studies indicate that the source of algal bloom, symptomatic of eutrophication in lakes, is more closely associated with the presence of carbonaceous materials (as measured by BOD) than with the presence of nitrate and phosphate nutrients. Winneberger notes:

> In the interim, an honest scientist can only express his opinion while declaring his ignorance of any scientifically sound criteria for the potential eutrophication

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*Louchs, D. P. Models for Water Pollution Control Policy Analysis, Presented at the 38th National Meeting of the Operations Research Society of America, October 28-30, 1970.

**Private Communications, Dr. J. H. Winneberger, Septic Tank Consultant, formerly associated with the University of California Sanitary Engineering Research Laboratory.

> of waters. Further, any limits of tolerance set by regulatory agencies to control eutrophication would be strictly arbitrary and probably prejudice valid uses of lakes or streams.*

Winneberger's beliefs are based upon extensive review of the available literature, his own research experience, and his familiarity with current technology application as practiced in the field.

In their extensive review of the literature and their own research on these subjects, McGauhey and Krone** have examined the use of engineered soil systems for wastewater treatment. Appendix B contains a description of the details of their findings in these areas based upon empirical studies. In summarizing their conclusions concerning revival of bacteria and viruses, these two authors conclude:

> Research findings from studies of the travel of bacterial and viral pollutants with percolating water and with groundwater in saturated aquifers reveal a number of facts of engineering importance. Among the most pertinent are:
>
> (a) Bacteria behave like other particulate matter in soils and are removed by straining, sedimentation, entrapment, and absorption. In addition, they are subject to die away in an unfavorable environment.
>
> (b) The ability of bacteria as living matter with enzyme systems to move more freely than inert particles has not been evaluated, since most research has utilized living particles as the test material.

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*Winneberger, J. T. Potential Eutrophication of East Park Reservoir, Berkeley, California, November 1970.

**McGauhey and Krone. Soil Mantle as a Wastewater Treatment System, University of California, Berkeley, SERL Report 67-11, December 1967.

> (c) Coliform and other bacteria have been observed to move but a few feet with percolating water in unsaturated flow and a few hundred feet in groundwater in saturated systems.
>
> (d) Intestinal pathogens may survive in soil for periods up to about 2 months, depending upon the organic content of the soil, and retain their virulence during the period of survival.
>
> (e) Viruses are removed by soil systems, probably principally by absorption, as effectively as are bacteria.
>
> (f) It may be concluded that both biological antagonisms and physical removal of bacterial and viral cells characterize the change in biological quality of water percolating through a soil system; and that the system is a quite efficient device for removing such cells.

In summarizing their conclusions concerning the fate of some chemicals, McGauhey and Krone state:

> The ability of soil systems to remove chemicals from percolating water is quite limited. Biodegradable organic materials are normally attacked in the clogging zone and reduced to intermediate compounds and ultimately to stable compounds which characterize groundwater, e.g., nitrates, phosphates, carbonates, sulfates, etc. Concerning these and other ions which may come from industrial wastewaters, a number of important facts may be noted:
>
> (a) A considerable fraction of the 300 mg/l total dissolved solids added to water by domestic use appear as anions and cations normally found in groundwater. Thus, an increase in the normal mineralization of groundwater is to be expected if wastewater is percolated through a soil system. Under normal conditions of soil pH, phosphates are effectively removed. Chlorides, sulfates, and nitrates, however, move quite freely with percolating water and situations have already developed where nitrate content has limited the use of sewage effluents for groundwater recharge....

> (b) ...Synthetic detergents can be effectively destroyed by biochemical degradation in a biologically active aerobic soil system in which there is no escape of partially degraded material from the biosystem.
>
> (c) ...The foregoing findings refer, of course, to situations involving relatively bare soils. If the engineered system should make use of vegetation which is harvested, a considerable amount of nutrients may be taken up and so removed from percolating water.

From the findings and citations of the above-quoted authors, it is evident that there is considerable uncertainty, or at least diverse conclusions, among different authorities. In addition, it should be pointed out that soil conditions and hydrological characteristics and resultant events are quite variable within and between localities.

SOIL SUITABILITY CONDITIONS AND APPLICABILITY OF INDIVIDUAL SYSTEMS

Figure 5 depicts the geographical distribution of soil limitations for currently designed septic tank-soil absorption system operation. The criteria utilized to judge soil limitations are: soil permeability; shrink swell potential, the property of soils that "close up" when wet; water table levels; and excessive slope of terrain. The darkened areas are considered to have severe limitations and are not suitable for presently designed septic tank systems. Areas with moderate limitations are indicated by striped lines and constitute about 38 percent of the total area. Moderate limitations imply, relative to septic tank installation costs, significant costs to modify existing conditions in

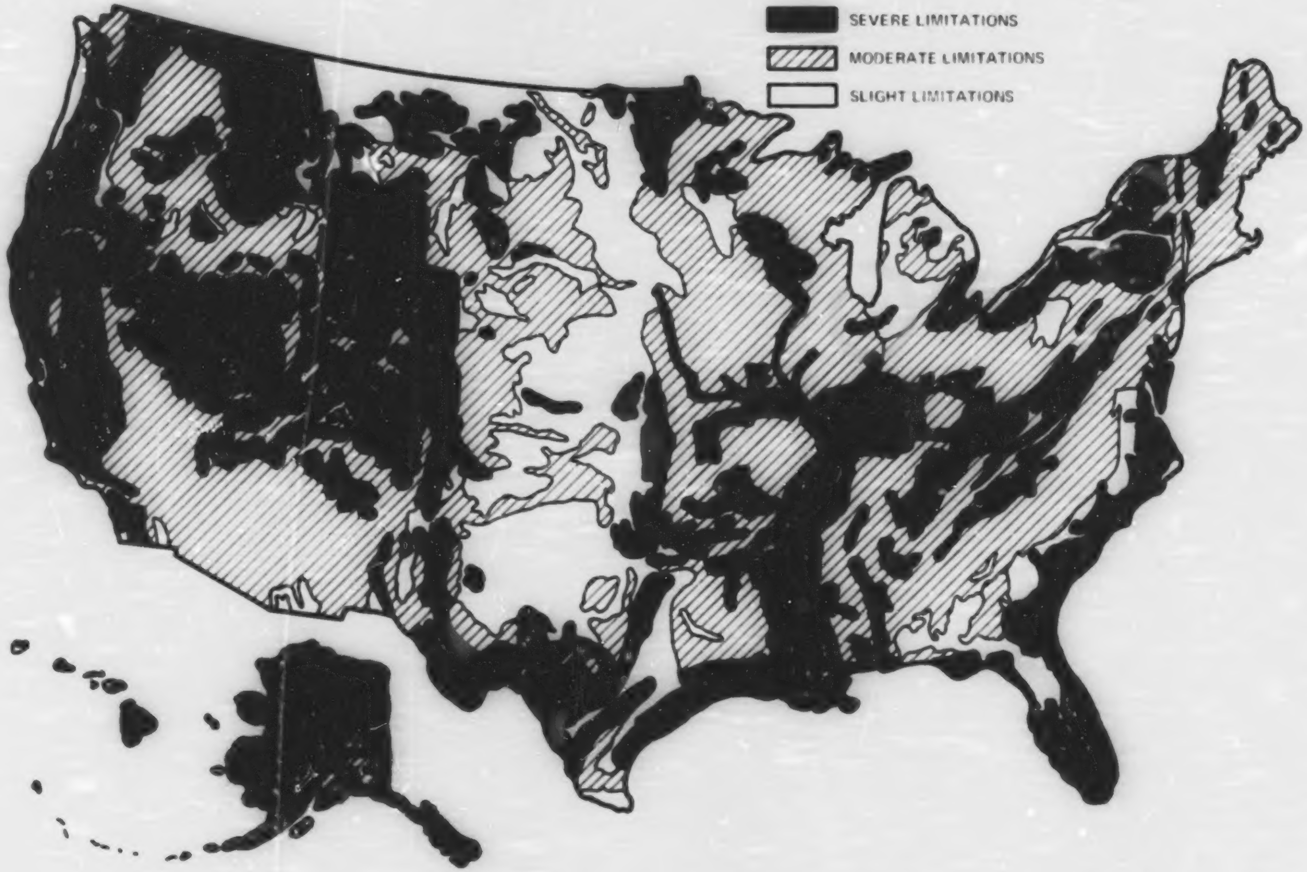
SEVERE LIMITATIONS
MODERATE LIMITATIONS
SLIGHT LIMITATIONS

FIGURE 5
DISTRIBUTION OF SOIL LIMITATIONS FOR SEPTIC TANK OPERATION

order to install a septic tank. Unmarked areas, about 16 percent, indicate areas of slight limitation.

However, these areas above are not homogeneous with respect to soil limitation. Utilizing an informed, unstructured Delphi-like technique, five experienced individuals of the Soil Survey Interpretation Branch of the Soil Conservation Service, U.S. Department of Agriculture, provided the following estimates of distribution of severe, moderate, and slight limitation within the areas so marked, based on a national level of aggregation.

AREA DELINEATION	PERCENT OF AREA CONSIDERED		
	Severe	Moderate	Slight
Percent of area delineated severe which was considered to be:	85	10	5
Percent of area delineated moderate which was considered to be:	65	20	15
Percent of area delineated slight which was considered to be:	35	20	45

These estimates, when applied to the above areas, indicate the following distribution of soil limitation conditions on a nationally aggregated basis:

Severe	68%
Moderate	16%
Slight	16%

As is always the case with highly aggregated figures, applications to specific local situations are not recommended.

Winneberger has indicated that considerable improvement would result from better soil engineering and management practices. Professor Bloodgood,* noting that a properly operated aerobic unit produces a clear effluent with a small suspended-solid content, especially if low-cost replaceable filters are used, estimated that at least 50 percent of land areas are suitable for effective operation of aerobic unit-soil absorption systems. He estimated the percentage of new individual homes that could use such systems as between 25-50 percent on a conservative basis. In addition, Bloodgood pointed out that connecting such systems to low-cost, small-diameter plastic-pipe collection systems (either pressure or vacuum) provides a significant potential for overcoming unsuitable soil conditions by moving sewage to suitable soil areas.

SUMMARY OF TECHNICAL CONSIDERATIONS

It is obvious that knowledge of the details of sewage composition, breakdown, and behavior in soil absorption systems is far from complete, and that there exists a diversity of opinions, often directly contradictory of one another, about details of the soil absorption and effluent conversion processes. Nevertheless, septic tank systems have functioned for many years without noticeable failure in communities all over the world. This would indicate that individual domestic waste treatment systems can indeed be designed for trouble-free operation and thus constitute a technically feasible alternative to central systems. The practice of individual system design must still include considerable art to supplement somewhat vague or scientifically unfounded available design criteria. Reliable techniques for predicting the capacity and ultimate suitability of soils for long-term absorption service on the basis of simple tests do not exist, though a non-specific "most conservative" approach based on unconventional, but experimentally supportable, principles of soil clogging has considerable merit. A related area of great uncertainty is whether organic loading (i.e., the amount of organics that have to be broken down in the soil) or hydraulic loading (i.e., the volume of liquid that must percolate through the soil) is the controlling design variable. The observation that continuous inundation with clear water is capable of causing clogging would indicate that hydraulic loading is the dominant consideration. On the other hand, since organic content apparently accelerates the clogging, a reduction of organic content might permit a soil system to recover more quickly. Thus, if systems are designed for periodic rest and recovery a more completely treated effluent might be disposed of in a smaller soil system. Too little thought appears to have been given to developing methods of predicting the possibility of contamination of ground and/or surface waters with effluents from specific absorption systems, though soil and geological maps can provide good clues to such possibilities. One purpose of a soundly based demonstration program would be to clarify these issues.

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*Personal Communication, Dr. Bloodgood, Purdue University.

SECTION IV

ECONOMIC ANALYSES OF INDIVIDUAL AND CENTRAL SEWAGE SYSTEMS

GENERAL

Attempts to compare costs of individual systems with central ones can yield very misleading results. If highly aggregated average costs are used to compute expected costs for a community, actual costs for a real situation for either alternative could easily be off by a factor of 5 or even 10. This is largely because of highly variable topographical and soil conditions which can drastically alter costs of digging for sewers or requirements for pumping stations as well as requirements for soil absorption bed sizes or other special precautions. On the other hand, if a specific example is taken, one can justifiably argue that the results are applicable only to that example and that each other situation would yield different numbers. Considerable resource expenditures would be required to work out detailed cost comparisons for many specific examples in an attempt to achieve a representation of the range of actual cost variability. Despite such shortcomings, it is useful to consider several comparisons between central and individual sewage waste treatment systems. Among other things, they all show that one can rationally arrive at a boundary between regions where centralized systems would be the preferred choice and areas where individual treatment is more advantageous. The location of the boundary, while largely a matter of economic and technological considerations, will be sensitive to such other factors as topography, soil conditions, relative images/reputations of the two alternatives, etc.

RECENT STUDIES

In a "Feasibility Study of Technical Alternatives in Norwich, Vermont"*presented in March 1971, Werre estimated that a proposed central sewage collection, conveyance, and treatment system which had been designed and recommended for Norwich, Vermont, would cost $418 annually per household, based on $6970 investment cost amortized over a 50-year system lifetime at 5% interest rate and annual operation and maintenance (O&M) charges of $36 (essentially the annual sewer bill). Werre concluded that if the recommended sewer system were to be extended to homes not included in the original design, the capital costs per household could drop from $6970 to as low as $6090, which would result in a drop in the annualized cost from $418 to $370. Against this range, various types of septic tank and leach field (soil absorption system) systems were estimated to cost from $250 (septic tank with NoDak evapotranspiration bed) to $104 (septic tank with two alternating leach fields and dosing system) on an annualized basis over a 25-year system life. In summary, for Norwich, Vermont, Werre estimated an annualized range of $370-$418 per household per year for sewers versus a range of $104-$250 per year for systems employing septic tanks and some form of subsurface

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*Werre, M. A. "Feasibility Study of Technical Alternatives in Norwich, Vermont," in Proceedings of Sewage Treatment in Small Towns and Rural Areas, A Conference Addressed Primarily to the State of Vermont, Thayer School of Engineering, Dartmouth College, Hanover, N.H., March 3, 1971.

soil absorption. These are full costs which do not reflect any governmental grants-in-aid for construction.*

Downing has made a detailed study of "The Economics of Urban Sewage Disposal."** The key portions of his study which deal with individual systems (septic tanks, in particular) are also summarized in a recent journal article.*** Based on calculations for a hypothetical community, Downing's results indicate that the extension of existing centralized system facilities to new subdivisions at the urban fringes ("low estimate") is just competitive with the installation of septic tanks at densities somewhat greater than four people per acre if the subdivision were 10 miles distant from the treatment plant; slightly less than 16 people per acre for 15 miles; slightly less than 64 people for 25 miles, etc. If the existing collection system were already at capacity, thus necessitating new sewer lines all the way to the treatment plant ("high estimate"), densities of more than 16 people per acre at 10 miles, and about 64 people per acre at 25 miles would be required before centralized systems would be less costly than septic tanks.

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*While grants could make central systems appear as cheap or cheaper than individual systems to the individual homeowners, individual and collective systems are treated on an equal, no-subsidy basis in this report. The subsidy issue, it may be noted, can be a two-edged sword, for aid-granting agencies could view individual systems which are purchased wholly with private funds as the minimum-cost alternative to the agency.

**Downing, P. B. The Economics of Urban Sewage Disposal, Frederick A. Praeger, Publishers, New York, 1970.

***Downing, P. B. "Extension of Sewer Service at the Urban-Rural Fringe," Land Economics, Vol. XLV, No. 1, February 1969, pp. 103-111.

These estimates were based on an average septic tank system lifetime of 35 years. Very low density areas far from the treatment plant would find septic tank systems more advantageous economically than centralized systems for septic system lifetimes shorter than 35 years. For example, in the low estimate (hookup to existing sewer lines all the way), even a 34-year lifetime would make septic tanks competitive at 4 people per acre and 25 miles from the treatment plant, while for the high estimate (again at 4 / acre, 25 miles) an average lifetime for septic systems of only 11 years' average would be competitive.*

Estimates of the influence of soil conditions on design lifetime of individual systems were given by Thomas, et al., who devised a mathematical model for determining economically optimal design lifetimes on the basis of soil uptake capacities, interest (or discount) rates, and renewal costs. For a 6 percent interest rate and average renewal costs, Thomas et al. estimated that the optimal system would have design lifetimes of 15 years for good soils and 5 years for poor soils.** With lower interest rates and higher replacement costs, a more costly design providing greater reserve capacity would have been optimal, and design lifetimes of as great as 40 years for good soil and 20 years for poor soils were indicated by the model.

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*Ibid.

**Thomas, H. A., J. B. Coulter, T. W. Bendixen, and A. B. Edwards. Individual Household Sewage Disposal Systems - Developing Technology, Cost Analysis and Research Needs, A Report to the Committee on Sanitary Engineering and Environment and the Subcommittee on Waste Disposal of the National Research Council, Division of Medical Science, Ca. 1958. Also published in Journal Water Pollution Control Assoc., Ca. 1960.

Werre's analysis treated a specific community with well defined sets of alternative plans for waste treatment. Against a background of real community cases for data and practical considerations, Downing's analysis refers to hypothetical average communities. Wenk undertook the analysis of the sewering vs. individual treatment problem on a national scale with highly aggregated population projections and realistic average estimating relationships.* While this approach could serve only as a starting point in analyzing the problem for any particular community, it assumes increased validity on the national level for which average conditions may be assumed to hold. In the following section, Wenk's approach as modified for use in this analysis will be referred to as the MITRE model.

THE MITRE MODEL

The MITRE economic and environmental impact model addresses aggregate resultants of providing new sewage facilities to that portion of the population which is projected to occupy new individual homes constructed during the 1970-1989 period. Resultant consequences are examined as a function of varying degrees of rapidity of utilization of individual waste disposal systems. That portion of this population not using individual systems is assumed to be served by centralized collection, conveyance, treatment, and disposal facilities. Various technological options are considered for collective systems and four different design populations are utilized. Based upon available data, the present value of the future costs of providing sewage service to this population, as a function of the mix of individual and collective systems, is derived. In this fashion, the economic costs of varying patterns of technology diffusion, themselves functions of action options selected, can be evaluated. Dependent upon the degree of centralized treatment removal of BOD assumed, the decrease in the load of oxygen-demanding wastes placed upon assimilative capacities of surface streams as a function of the amount of individual system technology in use is calculated. Similarly, the amount of water returned to soils and ground waters may be approximated in the aggregate, and the corresponding proportional possibility of pollution of ground water reserves gauged.

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*Wenk, V. D. A Technology Assessment Methodology, Water Pollution: Domestic Wastes, Vol. 6, MTR-6009, MITRE Corp., June 1971.

Expenditures for individual and collective pollution control assets and services are projected for each year in the examined time frame. These dollar figures could be converted to employment levels associated with these and linked industries if appropriate conversion figures were available or derivable. Dependent upon action options concerning the role of state, local, and federal agencies' participation in individual system and collective system programs, the impact on these agencies' budgets and operations may be inferred. A detailed description of the model is contained in Appendix C. A brief description is provided below. It is recognized that the highly aggregated level of this model prohibits examination of detailed consequences dependent upon local conditions and situations. One can only go so far with such an approach. The nature of major aspects of water pollution problems is such that discussions not imbedded in the realities of particular geographical and physical locations may lose their true significance.

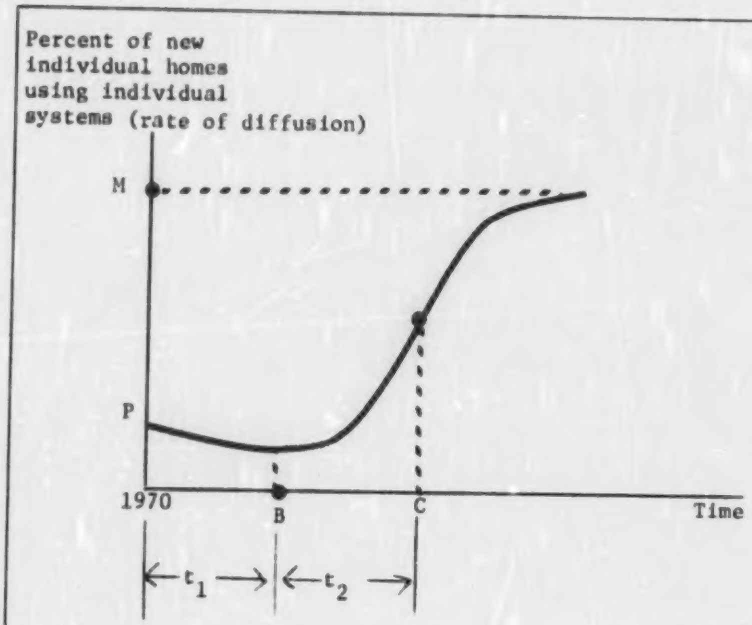
DESCRIPTION OF THE MODEL

The starting point in this model is projected population growth. Based on the Census Bureau Series D estimate of population growth and estimates of housing supply based on this projection, a forecast of the number of new individual homes constructed each year from 1970 - 1989 is derived. At this point, it should be clearly stated that there is nothing sacrosanct about the various approximations and estimates utilized in this model. The model is constructed in such a fashion as to allow alternative projections and estimates to be substituted directly or with minor modification.

The parameter chosen to represent the rate and magnitude of individual home system technology diffusion is the percentage of new homes constructed using such technology each year. This percentage is governed by three major parameters: the time delay (t_1) until this technology begins to be utilized in quantity; the speed with which such technology is adopted given that utilization begins (t_2); and the maximum percentage of new homes which can utilize this technology (M).

At a point in time, the portion of the population below this curve is served by individual systems and the portion above the curve by collective systems. The correspondence between the parameters

The figure below indicates the form of technology diffusion utilized:


Percent of new individual homes using individual systems (rate of diffusion)
M
P
1970
B
C
Time
t_1
t_2

P - Percent of new homes using individual systems in 1970

B - Time at which new individual system technology begins to diffuse = 1970 + t_1

C - Time at which one half the difference between the rate of diffusion at B and the maximum rate of diffusion is achieved = 1970 + t_1 + t_2

M - The maximum percent of newly constructed homes utilizing individual systems

FIGURE 6

ANNUAL UTILIZATION CURVE FOR INDIVIDUAL SYSTEMS

t_1, t_2, and M and various action items is discussed in the section of this report concerned with initial values and assumptions.

Based upon data obtained, the costs of providing the portion of the population on collective systems with sewage service are derived in terms of investment costs and periodic operating expenses. Investment costs include costs of constructing: treatment plants; ancillary works such as interceptors, lift stations, and outfalls; municipal collection systems; and house sewer connections. Periodic expenses including operational and maintenance costs of treatment plants and associated needed works are calculated and costed as a function of the secondary and tertiary treatment technology utilized and the design capacity of the system. Four alternative sized plants are costed out--ranging from design populations of 10,000 to 100,000 persons. The costs of centralized treatment are discounted back to present value of future costs for a twenty-year planning horizon.

Similarly, the present value of future costs incurred by the portion of this population using individual systems is determined as a function of initial investment costs of individual systems, periodic O & M costs, and economic life of the individual systems. In this fashion, the total financial cost of providing sewage service to this total population may be approximated under a variety of systems as influenced by expected resultants of various action options. The following are the variable inputs that are provided to the model, each representing a possible tradeoff area:

- The projected population 1970-1989;
- The number of housing units supplied 1970-1989;
- The number of individual homes supplied 1970-1989;
- The present rate of utilization of individual systems 1970;
- The number of years before new individual system technology begins to be widely utilized;
- The rapidity with which the technology is adopted;
- The maximum percentage of new homes that could utilize such technology;
- Investment cost of individual systems 1970-1989;
- Periodic annual O&M expenses for individual systems 1970-1989;
- The economic life of individual systems;
- Type of secondary and tertiary treatment provided in centralized systems and their utilization patterns;
- The design population chosen for centralized system treatment plants;
- Economic lives of treatment plants and sewer systems; and
- The discount rate to be used in arriving at present value.

Costs of conventional centralized treatment systems and associated works are programmed into the model based on available statistical studies of current construction and operating cost relationships as described in Appendix C. The model is programmed in FORTRAN both for a computer time sharing terminal and for batch processing.

Output of the model includes:

- The number of new homes utilizing individual systems each year 1970-1989;
- The stream of expenditures associated with individual systems each year 1970-1989;
- The present value of individual systems investment and operating costs in the 1970-1989 period;
- The population using collective systems each year 1970-1989;
- The stream of expenditures associated with centralized systems each year 1970-1989;
- The present value of collective system investment and operating costs in the 1970-1989 period;
- The number of collective system treatment plants needed for each of four design populations;
- The "market" for each of the two approaches each year 1970-1989; and
- The total present value of sewage services for the totality of this population.

In addition to these outputs, it is straightforward to evaluate for each pattern of technology diffusion:

- The decrease in the total BOD load on surface streams, as a function of plant performance each year 1970-1989 for various patterns of utilization of individual systems;
- Amount of treated wastewater returned to soils and ground water each year 1970-1989 and thus an indicator of potential ground water reserve pollution; and
- Manpower requirements for production, operations, and maintenance activities may also be derived if appropriate conversion constants could be determined.

The quantitative results of this model are discussed in the next section, Exercising the Model.

SECTION V

EXERCISING THE MODEL

The model allows examination of many combinations of input parameters which describe different "scenarios" including the exercise of action options. Action options can result in changes in the values of the three parameters that are used to describe technology diffusion (t_1, t_2, and M), changes in the economic life of individual systems, and changes in the costs of individual systems. In addition, changes in other inputs to the model correspond to generation of different scenarios. The following paragraphs describe the values of the inputs which were examined and the situations to which they correspond.

INDIVIDUAL SYSTEM PARAMETERS

Seven parameters describe characteristics of individual waste treatment systems of major importance. These parameters are:

(a) the investment cost, including the soil treatment systems

(b) the periodic expenses associated with operation and maintenance of aerobic systems and septic tank systems

(c) the economic life of individual systems including the soil treatment system

(d) the percent (P) of new individual homes using individual systems in 1970

(e) the maximum percentage (M) of new individual homes which cound utilize individual systems, i.e., the saturation level of individual systems

(f) the time delay (t_1) to the onset of appreciable diffusion of individual aerobic systems

(g) the speed with which individual system technology is utilized given that diffusion has begun. This is represented by the parameter t_2, the time after t_1 at which the percentage of new homes utilizing this technology is midway between the maximum value M and the value at time t_1.

The values of these parameters that were examined are indicated below. Only a limited but representative range of values was examined.

Investment Costs and Periodic Expenses

The pattern of technology diffusion utilized depicts a decreasing percentage of use of individual systems before t_1. This period corresponds to the observed decreasing relative use of septic tank-soil absorption systems in new individual home construction. At time t_1 new or improved system technology begins to gain widespread utilization. The investment costs utilized in the model are $1000 before t_1, corresponding to septic tank-soil absorption systems. After t_1 investment costs characterizing improved septic or aerobic systems are used. A value of $1250 was used for the calculations in this report. This is generally characteristic of aerobic systems, and improved septic tank systems could easily increase in cost to this value.

Periodic costs before t_1 consist of inspection and pumpout costs associated with septic tanks. An annual expense of $15 is assumed corresponding to pumping at 3-5 year intervals. After t_1 the periodic expenses of septic tank systems are assumed to double to $30, reflecting widespread and regular inspections and cost increases consistent with an improved public image. Periodic expenses of aerobic units consist of electrical power expenses and the annual fee for a maintenance contract. A value of $75 per year is assumed for aerobic units after t_1.

Economic Life of Individual Systems

The economic life of properly designed and operated septic tank-soil absorption systems could be well in excess of twenty years. Aerobic units have not received extensive accelerated life testing or been in use for sufficient time to establish their economic life. However, manufacturers' estimates indicate a twenty to twenty-five year life is likely if a maintenance contract continues in effect during the system life. A twenty year economic life is assumed for all individual systems.

Current Utilization of Individual Systems

The percent of new individual homes using individual systems, P, in 1970 is not a precisely known figure. The U.S. Public Health Service estimated that in 1967, twenty-five percent of new homes were being constructed with individual systems. Federal Housing Administration records indicate a ten-percent utilization in 1967. A value of 15 percent is assumed for P in these calculations.

Technology Diffusion Parameters

The following values of t_1 and t_2 are used in the calculations: $t_1 = 5$; $t_2 = 5$ and 10 years.* The three values of M used - 25%, 33%, and 40% - correspond to low, medium, and high estimates of the maximum percent of new individual homes constructed in the 1970-1989 period which could effectively utilize individual waste treatment systems.

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*These are the only values reported herein; though the model was exercised for all combinations of t_1 and t_2 values of 5, 10, and 15 years. Results of those caluclations can be made available to interested parties.

CENTRALIZED SYSTEM PARAMETERS

The statistical cost relationships used in describing centralized system investment and periodic costs are described in Appendix C. The major parameters describing characteristics of centralized system design over and above those built into these cost relationships are:

(a) The type of secondary treatment technology used

(b) The type of tertiary treatment technology used

(c) The design population of centralized systems

(d) The economic life of treatment plants and sewer systems

(e) The average number of persons per individual home

The following values for these parameters were examined:

Type of Secondary Treatment Technology

Two types of secondary treatment technology are considered, activated sludge and trickling filter treatment plants. It is assumed that, due to the higher performance of activated sludge plants, two-thirds of new construction plants will utilize activated sludge treatment at the secondary level and one-third will use trickling filter technology.

Tertiary Treatment Technology

Six tertiary treatment technologies are provided for in the model. These processes are sequential, each aimed at improving a single aspect of waste treatment. Tertiary treatment, really a collection of specific processes, is currently expected to increase treatment costs appreciably. The model was exercised under four different sets of assumptions about tertiary treatment: (1) lower bound, none used; (2) each of the tertiary processes is used in one-sixth of the plants; (3) each tertiary process is used on one-half of the treatment plants; and (4) the upper bound, all plants each use all six tertiary processes.

These four cases are intended to only approximate different patterns of tertiary treatment utilization and to bracket the cost ranges of introducing tertiary treatment in central system construction serving new home construction. Further investigation of the full cost implications of tertiary treatment is warranted, but must be based upon a survey of needs for tertiary treatment at specific locations.

Design Population

Conventional engineering design practice calls for designing treatment plants sized to treat the expected population to be served twenty years after initial construction. Fundamental questions of uncertainty of population growth and construction of excess capacity bear on the wisdom of this practice as do economics of scale in plant construction. This practice is reflected in these calculations. Four values of design capacity are examined: 10,000, 20,000, 50,000 and 100,000 persons. Economy of scale benefits are believed to be gained below the 10-30 million gallon per day design range. Available data limits the range of cost relationships to 100,000 persons or approximately a 10 million gallon per day design flow.

Economic Life

An economic life of 25 years is assumed for treatment plants and 50 years is assumed for sewer systems. These figures reflect current engineering design criteria.

Persons per Household

A value of 3.5 persons per individual home is used in these calculations.

Discount Rates

In the present value calculations performed, a discount rate of 6 percent is used for both centralized and individual systems.

RESULTS OF EXERCISING THE MITRE MODEL

For any particular choice of input parameters (e.g., t_1, t_2, P, M, secondary and tertiary treatment breakouts, discount rates, lifetimes of various subsystems, planning horizon), four pages are output by the computer:

Page 1 - "Projected Demand for Individual and Central Sewage Systems," which gives a year-by-year incremental and cumulative projection of new individual home population as well as the breakout between individual and central systems that corresponds to the set of input parameters.

Page 2 - "Investment Costs and Periodic Expenses Pattern for Individual Systems," which gives the yearly totals of fixed expenditures for individual systems; the total periodic expenses, by year, of all individual systems which would have been installed since the beginning of the planning period; the yearly sum of these two; and, finally, the total present value of the individual system expenditure stream (adjusted for salvage value of systems whose assumed lifetimes extend beyond the planning horizon).*

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*1970 was used as the base year in the planning period mainly because most of the cost-estimating equations had either been based on or had been converted to 1970 costs, but any other base year could be used if the cost relationships and the population projections were made available.

Page 3 - "Investment Costs and Periodic Expenses Pattern for Central Systems," which lists the number of systems required, the treatment costs, ancillary costs, other costs (defined in Appendix C) plus their total (total investment costs) for central systems for four different design populations (10-, 25-, 50- and 100-thousand people) as well as the annual time stream of periodic expenses for each design population; the total present value of the central system expenditure stream is given for each design population. This number (because it is adjusted for salvage value at the end of the planning period, and because all future costs are discounted back to present value) generally turns out to be lower than the total investment costs.

Page 4 - "Summary of Sewage System Costs," the total present value of the individual systems, the numbers of central systems and their total present value for the four design populations, and the total present value of sewage systems for the new individual home population (individual plus central).

In all cases, the values of the input parameters associated with the particular page of output are given at the bottom of that page. All other parameters remaining constant, one value of t_1 (=5), two values of t_2 (=5, 10), one value of P (=.15), three values of M (=.25, .33, .40), and four sets of assumptions about the extent tertiary treatment yield 24 output sets with an additional four for the baseline case (t_1 = 50 years). This yields 112 pages of output in all, just for the case of septic tanks followed by improved septic tank practices after t_1. Rerunning the problem for the case of aerobic tanks taking over after t_1 would yield another 48 pages of new information in sequence.* Only the output of the baseline cases (t_1 = 50, all four conditions of tertiary treatment distribution) and the cases of rapid new technology diffusion with average M (t_1 = t_2 = 5; M = .33; all four tertiary cases) are reproduced completely in Appendix D. Summary pages are reproduced for the remaining cases.

Basic Cost Implications

Table III contains the present values of costs of individual, central, and total (individual plus central) systems for different system mixes and different intensities of tertiary treatment. Septic-tank-based systems are assumed to be used throughout the planning period. In every block the individual system cost is given in the first column of the upper row, followed by the central system costs in the remaining four columns of the first row, and the total (individual plus central) is given in the last four columns of the second row. For example, for Case 1 (t_1 = t_2 = 5, M = .33) and 1/6 coverage for each tertiary process, the present value of individual system costs, $3,497 million is found on line 5, column 6, followed by the four central system costs in columns 7-10, and the four total system costs (individual plus central) are given in the next line, 6, in columns 7-10.

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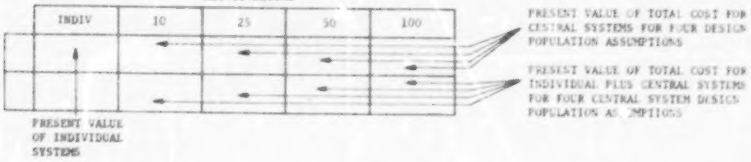
*Pages 1 and 3 of the output are identical for all individual systems, since page 1 concerns the demand projection, and page 3 concerns central systems only.

A

(Millions of Dollars)

				NO TERTIARY					1/6 TERTIARY					1/2 TERTIARY					
					DESIGN POPULATION (thousands)					DESIGN POPULATION (thousands)					DESIGN POPULATION (thousands)				
				INDIV.	10	25	50	100	INDIV.	10	25	50	100	INDIV.	10	25	50	100	INDIV.
				(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
t_1 = 50 Base Case	Independent of t_2, M, U(2) and PE(2) for 20 year planning period		(1)	1,485	37,656	35,060	33,483	32,185	1,485	41,054	37,476	35,378	33,695	1,485	47,898	42,338	39,192	36,722	1,485
			(2)		39,141	36,545	34,968	33,670		42,540	38,962	36,863	35,180		49.383	43,824	40,678	38,208	
t_1 = 5	t_2 = 5	M = .25	(3)	2,991	33,445	31,127	29,735	28,578	2,991	36,511	33,30[illegible]	31,438	29,929	2,991	42,686	37,684	34,875	32,658	2,991
			(4)		36,436	34,118	32,726	31,568		39,502	36,295	34,428	32,920		45,676	40,674	37,866	35,649	
		(CASE 1) M = .33	(5)	3,497	31,682	29,483	28,155	27,055	3,497	34,611	31,560	29,777	28,351	3,497	40,501	35,736	33,054	30,963	3,497
			(6)		35,179	32,980	31,652	30,552		38,108	35,057	33,274	31,848		43,998	39,233	36,552	34,460	
		M = .40	(7)	3,943	30,116	28,023	26,750	25,703	3,943	32,918	30,009	28,307	26,933	3,943	38,560	34,009	31,436	29,419	3,943
			(8)		34,058	31,966	30,693	29,646		36,860	33,952	32,249	30,876		42,503	37,952	35,378	33,361	
	t_2 = 10	M = .25	(9)	2,609	34,596	32,204	30,750	29,569	2,609	37,755	34,448	32,508	30,965	2,609	44,115	38,962	36,044	33,773	2,609
			(10)		37,205	34,813	33,359	32,178		40,364	37,057	35,117	33,574		46,724	41,571	38,653	36,382	
		(CASE 2) M = .33	(11)	2,873	33,566	31,238	29,833	28,672	2,873	36,646	33,423	31,542	30,032	2,873	42,843	37,819	34,992	32,771	2,873
			(12)		36,438	34,110	32,706	31,544		39,519	36,296	34,415	32,905		45,716	40,692	37,865	35,644	
		M = .40	(13)	3,096	32,670	30,401	29,032	27,916	3,096	35,680	32,538	30,702	29,241	3,096	41,737	36,835	34,069	31,917	3,096
			(14)		35,766	33,497	32,128	31,012		38,776	35,634	33,798	32,337		44,833	39,931	37,165	35,013	

KEY TO BLOCKS


INDIV
10
25
50
100
PRESENT VALUE OF TOTAL COST FOR CENTRAL SYSTEMS FOR FOUR DESIGN POPULATION ASSUMPTIONS
PRESENT VALUE OF TOTAL COST FOR INDIVIDUAL PLUS CENTRAL SYSTEMS FOR FOUR CENTRAL SYSTEM DESIGN POPULATION ASSUMPTIONS
PRESENT VALUE OF INDIVIDUAL SYSTEMS

B

of Dollars)

thousands)	1/2 TERTIARY					ALL TERTIARY				
		DESIGN POPULATION (thousands)					DESIGN POPULATION (thousands)			
100	INDIV.	10	25	50	100	INDIV.	10	25	50	100
(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
33,695	1,485	47,898	42,330	39,192	36,722	1,485	58,136	49,613	44,892	41,252
35,180		49,383	43,824	40,678	38,208		59,621	51,098	46,377	42,737
29,929	2,991	42,686	37,684	34,875	32,658	2,991	51,922	44,237	40,005	36,730
32,920		45,676	40,674	37,866	35,649		54,913	47,228	42,996	39,721
28,351	3,497	40,501	35,736	33,054	30,963	3,497	49,320	41,989	37,944	34,822
31,848		43,998	39,233	36,552	34,460		52,816	45,486	41,441	38,318
26,933	3,943	38,560	34,009	31,436	29,419	3,943	47,005	39,992	36,111	33,125
30,876		42,503	37,952	35,378	33,361		50,948	43,934	40,054	37,068
30,965	2,609	44,115	38,962	36,044	33,773	2,609	53,632	45,717	41,334	37,977
33,574		46,724	41, 71	38,653	36,382		56,241	48,326	43,943	40,586
30,032	2,873	42,843	37,419	34,992	32,771	2,873	52,119	44,400	40,141	36,854
32,905		45,716	40,692	37,865	35,644		5-,992	47,273	43,014	39,727
29,261	3,096	41,737	36,835	34,069	31,917	3,096	50,806	43,262	39,101	35,909
32,337		44,833	39,931	37,165	35,013		53,900	46,357	42,197	39,005

TABLE III
SUMMARY OF PRESENT VALUES OF WASTE
TREATMENT SYSTEM COSTS

TABLE IV

SUMMARY OF SAVINGS FROM INTRODUCTION OF IMPROVED INDIVIDUAL SYSTEM TECHNOLOGY - TOTAL SYSTEM COST DIFFERENCES

	NO TERTIARY Design Population (thou.)					1/6 TERTIARY Design Population (thou.)					1/2 TERTIARY Design Population (thou.)					ALL TERTIARY Design Population (thou.)				
	IND.	10	25	50	100	IND.	10	25	50	100	IND.	10	25	50	100	IND.	10	25	50	100
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
BASE CASE MINUS CASE 1, BILLIONS (Line 2 minus Line 6)		3.9	3.5	3.3	3.1		4.2	3.9	3.6	3.3		5.4	4.6	4.1	3.8		6.8	5.6	4.9	4.4
BASE CASE MINUS CASE 2, BILLIONS (Line 2 minus Line 12)		2.7	2.4	2.3	2.1		3.0	3.7	2.5	2.3		3.7	3.1	2.8	2.6		4.6	3.8	3.4	3.0

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Examination of Table III indicates that the present value of future costs decreases as design population of centralized systems increases, reflecting well-known economies of scale of centralized systems. The largest plant considered had a design population of 100,000 persons. Economies of scale in treatment plants are believed to cease somewhere in the 10-million gallon per day to 30-million gallon per day region. A design population of 100,000 corresponds roughly to a plant size of 10-million gallons per day.

The most basic and general cost figure to consider is the difference in present values of total system costs, a situation in which no improvements are made in individual systems (the base case), and a case in which technological improvements in individual systems practice are accompanied by rapid and widespread use of the technology (Case 1). These "savings" which could be expected from rapid development and diffusion of new individual system technology ($t_1 = t_2 = t_5$) are computed by subtracting line 2 of Table III from lines 4, 6, or 8, for M = .25, .33, or .44, respecrively. If a slower diffusion ($t_1 = 5$; $t_2 = 10$) is assumed, the savings can be found by subtracting line 2 from lines 10, 12, or 14 of Table III. The average expected savings, i.e., those for M = .33, are given in Table IV. The expected cost advantages of individual treatment systems are seen to range from present value differences of about \$3 to \$7 billion for the case of rapid diffusion, depending on the choice of assumptions about tertiary treatment coverage and the design populations. The corresponding range for a slower diffusion ($t_2 = 10$) is about \$2 to \$4.5 billion.

If a more complete diffusion (M = .40) is assumed, the expected cost advantages will be greater by increments of \$.5 to \$1.5 billions.

Inasmuch as the only difference between septic and aerobic systems that was reflected in the model runs was post-t_1 periodic expenses of \$30/year for septics versus \$75/year for aerobics, the aerobic system picture is similar, except that the higher total present values of the individual systems components reduce the expected cost advantage by almost \$1 billion. The ultimate coverage achievable with the aid of aerobic systems could be higher than that with septic systems alone if aerobic systems do indeed produce a more stabilized effluent than septic systems and if a reduction in organic loading can be translated into a reduction in absorption field requirements and thus permit the use of aerobic systems on smaller lots or areas otherwise unsuitable for septic tank effluent. Thus, for aerobics M = .4 might be an achievable goal, whereas M = .33 might be the most realistic figure for septic systems. In that case, the \$1 billion extra saving for greater utilization would just balance the \$1 billion extra cost of aerobic systems.

Actually, the model "sees" an individual system alternative only in terms of fixed and periodic costs, lifetime and the rate at which future costs are discounted to present value. Thus, any other individual system type could be simulated with the model, as could a predetermined mix of individual systems (by including average values for fixed and variable costs, etc.).

In a sense, the differences in present values between alternate approaches to waste treatment represent upper limits to the present value of effective investments in programs of research, development, demonstration, and diffusion of the new and improved individual treatment technologies. Since the potential savings depend on the amount and types of tertiary treatment which will be required to meet water quality standards (a highly uncertain area at present), the case where each of the six tertiary processes is used in 1/6 of the treatment plants ("1/6 tertiary") should yield a reasonable, if conservative, set of estimates. With all of the above considerations and uncertainties in mind, the likely present value cost advantage to be gained by rapidly developing and introducing new system technology is somewhat greater than $3 billion. Completely external to this figure are the dollar values of impacts on the environment and human health of the various system mixes.

DISTRIBUTION OF POPULATION BETWEEN INDIVIDUAL AND CENTRALIZED SYSTEMS

It is instructive to examine the projected utilization of individual systems for different combinations of diffusion parameters. The cumulative percent of individual homes built during the 1970-1989 period which use individual treatment technology at the end of the period is given in Table V.

It can be seen that, even under the most favorable circumstances ($t_1 = t_2 = 5$; $M = .40$), the overall percentage of homes using individual systems would only be 27 percent. For slower diffusion and less complete utilization ($t_1 = 5$; $t_2 = 10$; $m = .25$), the overall utilization at the

TABLE V

CUMULATIVE PERCENT OF NEW HOMES BUILT IN THE 1970-1989 PERIOD WHICH USE INDIVIDUAL WASTE TREATMENT SYSTEMS

$t = 50$	Baseline Case		8 (Percent)
$t_1 = 5$	$t_2 = 5$	$M = .25$	19
	$t_2 = 5$	$M = .33$	23
	$t_2 = 5$	$M = .40$	27
$t_1 = 5$	$t_2 = 10$	$M = .25$	16
	$t_2 = 10$	$M = .33$	18
	$t_2 = 10$	$M = .40$	21

end of the planning period would only be 16 percent, just slightly more than the 15-percent utilization rate assumed to occur at the beginning of the planning period. Furthermore, if no new or improved technology is introduced, the model predicts that only 8 percent of the individual housing units built in the 1970-1989 period would use individual waste treatment systems. The predictions are tied, of course, to the basic assumptions about the form of the annual utilization curve (Figure 6) as well as the assumed homebuilding projections.

MEASURES OF ENVIRONMENTAL IMPACT

At the highly aggregated level of the MITRE model it is difficult to address specific environmental consequences of utilization of individual systems. However, the decrease in annual BOD loading of surface streams due to use of individual systems by portions of the individual home population as opposed to the use of centralized systems can be calculated as can the amount of treated wastewater returned to soils and groundwaters. The latter quantity, itself a beneficial effect, is a crude indicator of probability of pollution of groundwater reserves, since the likelihood of this event should be proportional to the amount of groundwater recharge occurring. However, this is tempered by the ability of soil disposal systems to remove pollutants before entering groundwaters, as discussed in Chapter III.

Reduction in Annual Surface Stream BOD Loading

Based upon the assumption of a per capita daily generation of 1/6 lb. of BOD, and for specific percent BOD removal by centralized treatment plants, the reductions in BOD discharged to surface streams due to the use of individual systems may be calculated. Appendix D contains the year-by-year reductions in B loading for an individual system technology with: a diffusion pattern characterized by a five-year delay time, t_1; values to t_2 equal to 5 and 10 years; maximum percent utilization of individual systems of 25, 33, and 40 percent; and centralized treatment plant BOD removals of 85, 90, and 95%. Table VI indicates the annual BOD reduction, in thousands of tons per year, ascribable to the use of individual systems under the noted conditions in 1975, 1980, and 1989.

From Table VI it can be seen that an individual system technology, characterized by a 5 year delay time t_1, a value of t_2 of 5 years, and capable of ultimately serving 40 percent of new individual homes, will reduce annual surface stream BOD loading in 1989 by about 150, 100 and 50 thousand tons per year for centralized system BOD removals of 85, 90, and 95% respectively. Correspondingly smaller reductions in annual surface stream BOD loadings result from higher degrees of centralized system BOD removal (with correspondingly higher treatment investment and operating costs), smaller maximum potential percent utilization of individual systems, and slower rates of diffusion (t_2) of individual system technology.

INCREASE IN GROUNDWATER RECHARGE

The rate of groundwater recharge, and the accompanying possibility of pollution of groundwater reserves, is proportional to the amount of treated wastewater returned to soils and groundwaters. Not all of

TABLE VI

REDUCTION IN ANNUAL SURFACE STREAM BOD LOADING (thousand tons/year)

YEAR			1975			1980			1985			1989		
Centralized System BOD Removal %			85	90	95	85	90	95	85	90	95	85	90	95
t_1=50 (Baseline Case)			15.1	10.1	5.0	26.7	17.8	8.9	36.9	24.6	12.3	43.8	29.2	14.6
t_1=5	t_2=5	M=.25	15.6	10.6	5.2	38.7	25.8	12.9	72.4	48.2	24.1	102.4	68.3	34.1
	t_2=5	M=.33	15.8	10.5	5.3	43.4	28.8	14.4	87.2	58.1	29.1	126.9	84.6	42.3
	t_2=5	M=.40	15.9	10.6	5.3	47.2	31.5	15.8	100.3	66.9	33.5	148.7	99.1	49.5
t_1=5	t_2=10	M=.25	15.4	10.3	5.1	34.6	23.1	11.5	61.5	41.0	20.5	86.5	57.7	28.8
	t_2=10	M=.33	15.5	10.3	5.2	36.7	24.4	12.2	69.1	46.1	23.0	100.9	67.2	33.6
	t_2=10	M=.40	15.6	10.4	5.2	38.3	25.5	12.8	75.6	50.4	25.2	111.1	74.0	37.1

this return will contribute to groundwater recharge, however, due to losses to the atmosphere due to evaporation and evapotranspirative action of the vegetative groundcover. These conditions are variable and depend on local weather and soil conditions. The aggregate annual amount of treated wastewater from individual systems returned to soils and groundwaters is presented on a year-by-year basis in Appendix D for assumed levels of 80, 100, and 120 gallons per capita daily usage rates of water in the home. Table VII indicates the aggregate amount of returns to soils and groundwaters in billions of gallons per year in 1975, 1980, and 1989, resulting from individual system usage as indicated for each of the three levels of water usage. A value of $t_1 = 5$ years is assumed.

These figures indicate an annual return in 1989 of up to 1.4 trillion gallons per year, with correspondingly smaller returns for smaller maximum potential percent utilization of individual systems, slower rates of technology diffusion, and decreasing rates of water consumption. Not only groundwater recharge and possible pollution but changed hydrological balances between surface and groundwaters could possibly result.

COMMENT

The quantitative estimates above are representative of the usefulness of the economic and environmental impact model. Only a limited range of parameters has been examined but the capability for examining other situations of interest exists. The results of this model are probably best interpreted in a relative rather than absolute manner and as indicative of trends rather than specific predictions. As mentioned, only a few of the model run results are reproduced in full in Appendix D, with summaries of the others given for reasons of clarity and economy of presentation as well as paper. Complete results can be made available as required.

TABLE VII

INCREASE IN GROUNDWATER RECHARGE (billion gallons/year)

YEAR			1975			1980			1985			1989		
Daily Per Capita Water Utilization,gpcd			80	100	120	80	100	120	80	100	120	80	100	120
$t_1=50$	Baseline Case		96.5	121	145	171	214	257	236	296	355	281	351	421
$t_1=5$	$t_2=5$	M=.25	97.6	123	146	248	310	332	464	580	696	656	829	984
	$t_2=5$	M=.33	101	126	152	277	346	415	558	698	837	813	1016	1219
	$t_5=5$	M=.40	102	128	153	302	378	453	642	803	963	952	1190	1428
$t_1=5$	$t_2=10$	M-.25	98.9	124	148	221	276	332	394	493	591	554	693	831
	$t_2=10$	M=.33	99.4	124	149	235	294	352	443	553	664	646	807	969
	$t_2=10$	M=.40	99.7	125	150	246	308	369	484	605	726	712	890	1068

SECTION VI

INSTITUTIONAL CONSIDERATIONS

ADMINISTRATIVE ARRANGEMENTS

In considering the actual administration of waterborne waste policies and operations, a distinction should be made between: control and regulatory responsibilities; ownership; and responsibility for management and operation of whatever physical facilities and human material resources are involved. Although these aspects often blend together, the first, control and regulation, corresponds to the issues underlying effective formulation, promulgation and enforcement of standards as well as major degrees of influence on the selection of specific technological means to achieve environmental quality levels implicit in such standards. The latter facets of this administrative dichotomy, ownership and management, address the manner in which individuals singly or collectively organize to perform the function of waste disposal.

At one end of the spectrum is the pattern of individual ownership, operation, and maintenance of facilities. Of necessity, such a pattern involves a technology that must be simple, relatively trouble free, and in addition, to be effective, relies upon maintenance techniques easily within the grasp of the average citizen's abilities and disposition, or alternatively is easily obtainable as a commercial or public service at reasonable cost. Although septic tanks when properly designed and appropriately chosen for local soil suitability conditions, do meet the first requirements, difficulty exists in the area of proper maintenance practices. A good deal of misinformation as well as lack of information about proper maintenance procedures among homeowners, as well as some commercial septic tank maintenance firms, has been responsible for a large percentage of failures of such systems.*

Although it is not necessarily the case, individual home waste systems in the United States typically are owned and "operated" by the homeowner. The general patterns of control and regulation of performance rarely fall into the area of responsibility of public agencies once installation has been completed, except to the extent that failures, when and if reported, provide a hazard to public health. The major point of public agency control lies at the point of system selection. Approval of local, county, or state public health officials; sanitary agency officials; and zoning boards are typically prerequisite to selection and installation of individual systems. Thus, after installation, individual systems are clearly the responsibility of the individual who may or may not possess the knowledge required for effective post-installation practice.

Thomas *et al.* have directed attention to nations such as Switzerland and Sweden where administrative patterns have developed that place heavy reliance on "systematic detailed and periodic inspections of household disposal systems, together with long-accepted, efficient, and orderly legal processes for enforcement. Inexpensive tank cleaning and system maintenance is provided by service organizations that are a part of (or licensed by) the local department of public works."*

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*Private Communication, Mr. P. Rowen, Community and Facilities Development Division, Department of Housing and Urban Development.

In contrast with individual systems practices, the prevalent administrative pattern for centralized systems is one of public agency regulation, control, ownership, and management of operations. Although it is essential that effective control and regulatory power reside within the public domain, due to the essential community service nature of sanitary services, it is a distinct set of criteria that lead to the prevalent emphasis on public ownership, planning, and management of waste disposal assets. In addition to substantial arguments which support the choice of public ownership and management of what is essentially a utility, it should be pointed out that the failure to delegate the performance of this function to the private sector (even without delegation of control and regulatory functions) has also been a result of the lack of economic incentives associated with provision of sewage services. The individual waste generator has rarely been in the position of being economically penalized for inadequate waste disposal practices and therefore has had little incentive to transfer this responsibility to the private sector for a fee.

Local public agencies in the water pollution control field derive their authority from the state government through legislative action, and are thus empowered to construct and operate facilities, to raise funds through issuance of bonds and collection of service fees, and to accept federal grants.

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*Thomas et al., op. cit.

Other agencies, typically public health agencies, are empowered to ensure compliance with existing regulations concerning waste disposal as well as to approve sanitary facility plans of developing communities, commercial establishments, and subdivisions. Most of these efforts take place at a very local level.

Financial Considerations - Individual Systems

In new construction involving individual systems, the financial costs of construction are initially borne by the builders or developers and then directly passed on to the homebuyer. At this point, the homeowner completely absorbs all financial operating and maintenance costs. If any costs are passed on to society as a whole, then they relate to system malfunctions and overall costs of pollution to the extent that such costs exist in a specific locale.

It should be noted that the concept of a service contract embodies the idea of transferring maintenance responsibility from the domain of the homeowner to other agencies. As noted before, once installation inspections are completed, the only time non-homeowner-initiated actions take place for individual units is in the event of reported system failures. It is a logical extension to consider the possible role of public agencies in systematic management of individual systems in the U. S. as is the practice in European countries. Winneberger *

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*Private Communications, Dr. J. H. Winneberger, Septic Tank Consultant, formerly associated with the University of California Sanitary Engineering Research Laboratory.

has suggested the formation of district management of sewage service practices including septic tank operations Such districts, at the large subdivision level, would have authority to raise revenue for operations, enter property (not dwellings) for inspection, remedy overloaded systems, sewer areas if ever needed, and make ordinances governing sewage disposal practice. The district would have responsibility for initial designs, installations, and maintenance operations.

Financial Considerations - Centralized Systems

In constructing new centralized facilities, there are four prime sources of financial capital available. Viewed from the local level, the level at which constructive activity and operation usually take place, financing could be obtained from leasing techniques, pay-as-you-go techniques, borrowing, or outright grants from other levels of government. Leasing is not currently a realistic alternative, since this shifting of initial outlay costs to other levels of government or the private sector has not received widespread utilization. The concept of a "turn key" contract, wherein a community delegates responsibility for planning and constructing facilities within designated performance, cost, and schedule requirements, is not prevalent either.

The pay-as-you-go scheme, based upon the accumulation of capital funds prior to construction, is usually limited to nonmajor enlargement or alterations in facilities. Sources of these funds typically arise from utility fees, but legal restrictions concerning the accumulation of large balances limits this approach. Borrowing and grant acceptance are the dominant modes of local financing.

Borrowing, through issuance of bonds and special assessments, provides the prevalent means of raising funds to cover a local government's share of construction costs. The ability of a municipality to issue bonds derives from state laws controlling local government financing which typically include debt limitation, tax limitation, or interest rate limitation provisions. Debt limitations restrict outstanding debt to a percentage of real estate assessed valuations. Tax limitations restrict tax rates applied to debt service payments. Interest rate limitations place an upper limit on the interest paid on borrowed money. Municipal bonds usually require approval by voter referenda, and are quite sensitive to the voters' perception of their overall financial burden and their judgment as to the relative priorities of competing needs for funds such as education, transportation, and sanitary services.

The final, and often catalytic source of partial financing for local sewage operations is federal and state grant programs. State programs vary considerably from place to place. Major federal programs include: HUD Water and Sewer Facilities Grants; Economic Development Administration Public Works Grants and Loans; Farmers Home Administration Community Service Loans; and the Office of Water Programs Construction Grants, Training Grants, Comprehensive Basin Planning Grants, and Research Development and Demonstration Grants. The terms and conditions of these grant and loan mechanisms are quite variable. For example, the HUD water and sewer facilities program covers up to 50 percent of the costs of land and construction of new facilities if an area-wide program and comprehensive plan exists. The Economic Development Agency grant program can provide up to 50 percent of development costs of sewer systems in designated redevelopment areas and up to 80 percent in severely depressed areas. The Farmers Home Administration program provides grants for community service system construction in rural areas, including collection and treatment systems, as well as loans to individual low-to-moderate income families in rural areas, which can be applied to individual or collective waste disposal systems. Current Farmers Home Administration policy encourages centralized community facilities and restricts use of individual systems where feasible.

The Construction Grant Program provides grants to public bodies to assist with the cost of construction of treatment plants and interceptor sewers. Interceptor sewers, although not rigidly defined by funding federal agencies, often channel wastes from trunk sewers to treatment plants. Trunk sewers collect wastes from lateral sewers, which in turn are connected to homes and industries.

The magnitude of current construction grants varies between a maximum of 30 percent of "eligible" construction costs and a maximum of 55 percent,dependent upon the degree of state contribution to construction costs and the degree of compliance with certified area-wide comprehensive waste treatment plans.

Federal assistance programs contain either a requirement or strong policy guidance for funding of collective collection and treatment facilities owned and operated by public agencies. This feature introduces an immediate and strong force working against consideration of an "optimum" mix of centralized and decentralized systems. The possibility of using Section 8 grant funds for planning and construction of individual systems where ownership (and possible leaseback authority) resides with a duly constituted and technically competent public or quasi-public agency requires detailed examination since current legislation may allow such an interpretation.

Community Development Considerations*

The degree to which the forms of sewage services have noticeable impact on rational design of regional and community structure is an issue with no clear resolution. It is the resultant interaction of a complex of social and economic forces that dictates the nature of a community, only one of which is the chosen pattern of waste collection, conveyance, and treatment alternatives. Specific examples can be cited illustrating the attractive power of existing collective collection system to land development. On the other hand, patterns of "leapfrogging" which have been noted to contribute to "urban sprawl"** have had as contributing factors the technological possibility of utilizing individual home treatment and disposal systems, as have vacation home developments. Conversely, imposition of building moratoriums resulting from lack of adequate sewage treatment facilities, in Virginia and New Jersey for example, have restricted extension of existing patterns of development of several communities. At the same time, lack of soil conditions suitable for currently utilized individual home systems has prohibited development of areas which, because of locational, topographic, geologic, and financial considerations cannot support conventional collection and conveyance systems, or where treatment capacity is not available nor economically feasible.

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*Partially based upon: Grava, S. Urban Planning Aspects of Water Pollution Control, Columbia University Press, 1969, Chapter 7.

**Urban and Rural America: Policies for Future Growth, Advisory Commission on Intergovernmental Relations, Washington, D.C., April 1968.

By and large, individual home systems in the past have been limited to septic tanks, and currently all individual home systems are treated administratively as septic tanks. Yet in the choice of suburban sewage systems, no single precise agreed-upon answer exists as to population densities that dictate a collective system as opposed to individual septic tank system approach.

Given this situation with individual systems that have had widespread suburban application for over twenty-five years, it is not surprising that other individual home systems with significant operational differences and implications, and a good deal less widespread knowledge of their performance and proper management available, present significant evaluative problems.

Suburban areas can often be characterized as areas settled by families that expect and demand high-level public services. But suburban areas are often dominated by small political units which are inherently ill-adapted for provision of efficient engineering services in the form of public works improvements; as Grava notes:*

> It is not always reasonable to say that only municipal systems can be permitted since anything else is bound to pollute water or soil. Costs and habits are involved, and, as has been discussed, certain individual systems are acceptable under strict control in areas with suitable characteristics.
>
> The search of available literature will not give any answers to this question. The hints and assumptions which are found scattered here and there are not reliable since they are not backed up with adequate justification and technical proof. For example, suggestions that one family or two families per acre density is the threshold below which septic tanks are permissible, or that public sewers are rarely justified in areas with densities below 2,500 to 5,000 persons per square mile can be highly misleading in any particular case, although they may have some use as preliminary indications.
>
> It all depends on the substrata conditions on the site and locally defined levels of desired sanitation.

The situation is quite complex. From the builder's point of view, individual systems offer significant advantages when investment capital flexibility factors are considered, since such systems can be installed simultaneously with construction of each unit as distinct from sewer systems which require expensive preconstruction site developments. From the point of view of local regulatory agencies, a choice of individual systems requires approval of selected sites based on soil suitability criteria as well as system design parameters and inspection procedures to ensure proper installation on the part of the builder. Still another factor is the after-installation monitoring of operation practices. It is commonly accepted that monitoring and surveillance of municipal system waste treatment practices is an ongoing responsibility of public agencies. With individual systems, however, the pattern that has emerged is complete reliance upon individual homeowner behavior with involvement of public agencies occurring only after an incidence of system failure has been detected and reported.

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*Partially based on: Grava, op. cit.

Another sector of interest is the second-home, recreational, or vacation community. The population projection that was used in the MITRE model was based on housing construction projections which were furnished by the National Association of Home Builders (see Appendix C). These figures assume increased demands for second homes. Unless a community of second homes can easily hook up to a nearby existing centralized system, the developers or homeowners will be faced with deciding how to safely dispose of and treat their sewage. To the extent that second homes are not occupied year-round, individual systems which use soil absorption of effluents would have a built-in cycle of resting of the absorption field, and thus a principal contributor to individual system failure would be minimized.

Other types of individual systems which do not depend on soil absorption might likewise be more appropriate than sewers to the second-home communities. Examples are incinerator toilets and holding tanks (large receiving tanks which are pumped out by a collecting vehicle when full), for which annual costs quite obviously depend on occupancy patterns.* While vacation communities which provide a luxury to more affluent sectors of the population might seem less deserving of public assistance than primary residential (first home) communities which serve the basic needs for shelter, inadequate sewage practices in any sector of the population can adversely affect the population at large and the environment. Second homes are often built in "instant-community" developments in exurban areas in a manner not unlike the post World War II housing developments. Developers interested in quick sales and immediate profits can hardly be expected to have long-range interests of the community high among their priorities, nor can small local public health units be expected to present much deterrence to big land development interests whose building plans may be at variance with soil capabilities.

Individual home treatment systems will undoubtedly continue to be installed both in new residential communities and in recreational or other second-home developments. If governmental and sanitary commission authorities continue to view individual systems as individual responsibilities over which owners exercise complete sovereignty as long as things work right, significant numbers of systems will surely fail. Reliable engineering design guidelines, installation practices, inspection and maintenance procedures, and administrative arrangements for financing and implementing all of these improvements must be developed to ensure a degree of reliability and effectiveness for individual systems on a par with the best central system operations.

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*Schad, op. cit.

APPENDIX A

SOIL CLOGGING AND THE FAILURE OF SEPTIC TANK ABSORPTION SYSTEMS

SOIL CLOGGING AND THE FAILURE OF SEPTIC TANK ABSORPTION SYSTEMS

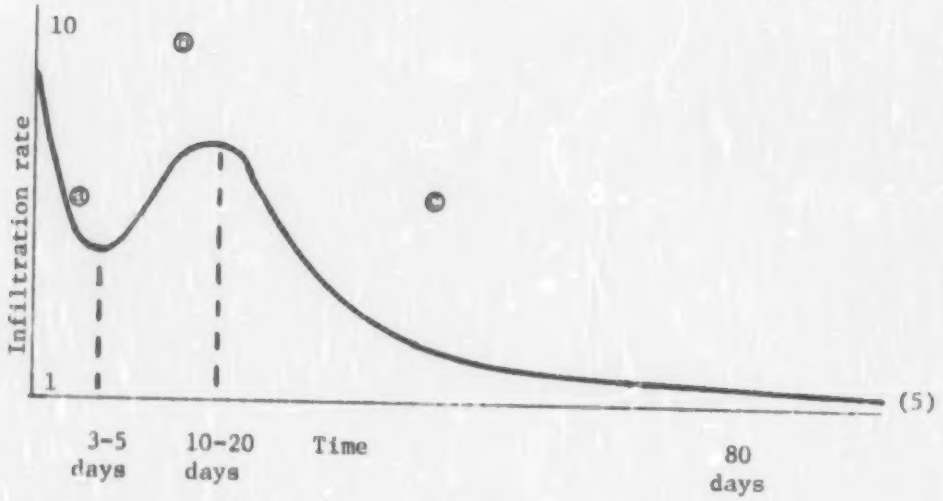
INTRODUCTION

Septic tank-soil absorption systems have reportedly had a high rate of failure in the past, with such failures occurring, in many instances, even though the septic tank itself had been operated in accord with recommended practice and the usual percolation tests had shown soil conditions to be acceptable.(1) Investigators have found this failure to be caused principally by the development, over time, of a clogging layer very close to the surface of the absorption field which slows and finally prevents entry of the wastewater into the soil system. (2, 3) Consequently, the success or failure of such systems appears to depend upon the infiltration rate of the liquid into the soil (the ability of the soil to accept water) rather than the percolation rate, or rate of movement of the liquid once it has entered the soil (the ability of the soil to dispose of water). (4) While the percolation rate, upon which the percolation test is based, depends to a great extent upon the physical characteristics of the soil (such as pore size) the infiltration rate is a function of the clogging material itself. (4) Suggested factors influencing the extent and rate of development of this material, in turn, have been method of wastewater application (dosing frequency, hydraulic load, extent of resting); content of the applied liquid (amount and type of BOD, COD, amount and size of suspended solids); and the physical and chemical characteristics of the soil (pore size, extent of aggregation, compaction, and chemistry of the soil). Because of these aspects, soil clogging typically does not show up during a short-term percolation test which uses clear water.

Clogging of the soil is, strictly speaking, a physical phenomenon, i.e., an increase in physical resistance to flow resulting from changed friction or viscosity coefficients or from reduction in size and volume of pore spaces.(3) Although microorganisms in the soil and their action upon organic matter both within the soil and in the added wastewater appear to be primarily responsible for soil clogging in most cases, the soil is extremely complex, as is the wastewater which it treats, and many factors can influence the infiltration rate. Physical and chemical factors will be discussed in addition to clogging by microbes and organic matter. The mechanisms to be reviewed in this Appendix occur in the short term, i.e., days or months, while functional failures of septic tank-soil absorption systems are a long-term affair, i.e., a period of years. It is not known whether the short-term mechanisms described herein are also responsible for the long-term failures. It is most reasonable to expect, however, that design precautions aimed at minimizing the short-term threat will at the very least slow the long-term failure mechanism by alleviating added stresses on the system.

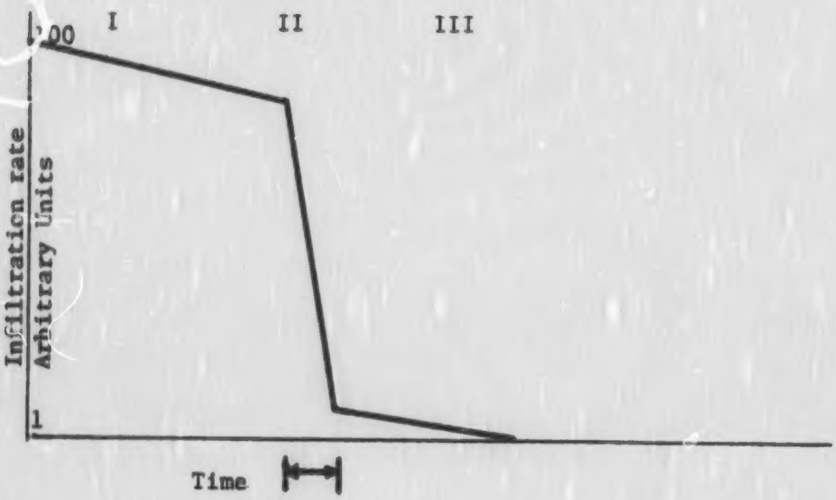
EXPERIMENTAL EVIDENCE AND PHASES OF CLOGGING

Experimentation has shown that infiltration rates in artificial soil absorption systems (lysimeters or soil columns) under continuous inundation with clean water follow a certain pattern (arbitrary units are shown):



The first stage (phase ⓐ) has been attributed to structural changes from the swelling and dispersion of dry soil on wetting and from dispersion resulting from a decrease in the electrolyte content of the soil solution as salts present are removed in the percolate. The increase in the second phase (phase ⓑ) appears to be due to the removal of air trapped in the pores as it dissolves in the percolating water; the maximum infiltration rate is attained when most of the air is removed.(5) The decrease in the third phase (phase ⓒ) is generally attributed to clogging.

When the inundate contains sewage, phase ⓑ may never occur, since phase ⓒ is accelerated such as to mask phase ⓑ. Thomas, Schwartz, and Bendixen,(2) subjecting lysimeters to intermittent dosing with septic tank effluent, failed to note any temporary recovery. The behavior of their lysimeter columns is indicated below (their three phases are labelled differently for clarity):



phase II ≈ 50 days

> "The first phase of behavior is a period during which there is a slow reduction in infiltration rate over an extended period of time. The second is a brief period during which the infiltration rate is so sharply reduced as to cause continuous inundation of the surface under the intermittent loading used. In the third phase, the infiltration rate asymptomatically approaches a lower limit." (2)

They further demonstrated that, upon cessation of sewage application and exposure of the soil surface to air, recovery of the system is first rapid and then slow, resembling progression through phases II and I backwards.

Since nitrification of the applied sewage, an aerobic process, ceases early in phase II, the authors conclude that the change from phase I to phase II coincides with a shift from aerobic to anaerobic soil conditions.(2) However, in other experiments by the same authors, when pore gas was actually measured, rapid soil clogging (characteristic of anaerobic conditions) started while oxygen concentration in the pore gas was greater than 13%. An explanation suggested for this phenomenon was that water-filled pores or water films occurring as a result of increased soil moisture may have provided anaerobic sites in the presence of high pore-gas oxygen.(7)

In addition to this, it is important to note Allison's experiments, in which (a) soil continuously submerged with clear water demonstrated phases ⓐ, ⓑ, and ⓒ; and (b) sterile soil inundated in sterile water displayed no decrease from phase ⓑ.(5) The implication is that phases ⓐ and ⓑ result from physical-chemical processes alone, while phase ⓒ, the clogging phase, includes the effects of biological activity. The experiments also indicate that clogging can result solely from the activity of soil microbes on soil organic matter.

Other experiments of Schwartz, Bendixen, and Thomas have important implications. In intermittent dosing of sand, liquid movement was found to strongly affect gas displacement. Each sewage dose was followed by an immediate reduction in pore gas volume, decrease in oxygen concentration, and increase in CO_2 concentration. Respective minimums and maximums were reached after infiltration was complete, and extreme values were followed by recovery to initial values, unless interrupted by another sewage dose. When sewage was applied in six doses per day, after 9 weeks the pore gas in the lysimeter failed to reach the initial value before the next dose. Each dose after this caused observable changes in the volume and composition of the pore gas; this stage of pore gas behavior was coincident with accelerated loss of infiltration rate. When the same amount of sewage was applied in two doses/day, there were greater extremes at the end of infiltration than in the six/day lysimeters, but the system also demonstrated a greater ability to return to initial values at a faster rate. Pore gas returned to initial values after individual doses until nitrogen was introduced at 20 weeks. While infiltration rate was erratic, it did not demonstrate the rapid decline characteristic of phase II and found in the 6/day lysimeters, and never became continuously inundated.(6)

As discussed by McGauhey and Krone in (3), the equilibrium infiltration rate approached by a soil system under continuous inundation is about the same for clear water as for sewage effluents; only the time required to reach it varies with the organic load.

From these experiments, several points become apparent:

(1) While other factors may contribute to clogging (e.g., suspended solids), microbial activity alone may produce severe clogging.

(2) While clogging may be more rapid in the presence of added organic matter, it can result entirely from the action of soil microbes on soil organic matter.

(3) Infiltration rate decreases over time when soil is under water. The rapid decrease in infiltration rate generally coincides

with a decrease in pore gas oxygen. Since the decrease in infiltration rate can occur even when there is nothing in the applied water that would apparently clog the soil, it appears that changes in the soil resulting from the presence of the water and/or the decrease in oxygen are primarily responsible for the decreased infiltration rate. Soil changes which have been noted during clogging are (1) increase in bacteria; (2) increase in polysaccharides; (3) increase in polyuronides; (4) increase in FeS. Soil changes leading to clogging may be accentuated by the organic matter in sewage effluent but apparently can occur in the absence of such additional material.

PHYSICAL AND CHEMICAL FACTORS IN SOIL CLOGGING

Physical Factors in Soil Clogging

Five ways in which clogging may result from predominantly physical phenomena are listed in Soil Mantle as a Wastewater Treatment System, McGauhey and Krone,(3) as quoted from an earlier article by McGauhey and Winneberger:

1. Compaction of soil by superimposed loads (e.g., ponded water, heavy equipment, etc);
2. Smearing of soil surfaces by excavating equipment;
3. Migration of fines by vibration of dry soil during preparation of site area;

4. Migration of fines due to rainfall beating against the surface;

5. Washdown of fines perched on larger particles.

These situations can prevent the entry of water into a soil, independent of oxygen levels in the soil, content of the applied water, or methods of application of the liquid. The first three are primarily due to ignorance, carelessness, or the improper use of machinery in the construction of the system, and the fourth is not relevant to septic tank absorption systems. Other factors such as retention of soil moisture by capillarity, thereby excluding oxygen and creating anaerobic conditions,(4) are also physical in nature, but really create situations in which microbial activity leads to clogging, rather than directly causing the clogging themselves. Mechanical filtration of particulate matter from the effluent has been shown to be a cause of initial reduction in infiltration rates(1) but will be discussed under "Biological and Organic Clogging." Physical factors probably affect all septic tank absorption systems to some extent.

Chemical Factors in Clogging

Three chemical factors appear important in soil clogging:

(1) Ion-Exchange Capacity of the Soil; Sodium/Total Cation Ratio in the Applied Wastewater

The sodium content of the soil has been recognized as an important factor in the suitability of some soils for use of septic tanks. A high concentration of sodium both in itself and in relation to other cations in the soil can, upon dilution by the application of water with a low salt concentration, cause the soil to disperse immediately and become sticky and relatively impermeable. This has been explained in the following manner:

> Movement of water through clayey soils at useful rates requires a physical arrangement of the mineral particles that provides pores which are large relative to clay mineral sizes. The formation and stability of aggregates of clay minerals, or of all of the size fractions present, requires cohesion of the particles under the prevailing physical, chemical, and biological conditions during use. The principal initial cohesive force in soils is the van der Waals force - an attraction of atoms for one another that is independent of direction, is additive, and has very short range....
>
> If a clay soil is to be used for water treatment the stability of wet aggregates during use is important. In a clay-water system the van der Waals attraction between two mineral particles is opposed by Coulombic repulsion of cations sorbed or held near the surfaces of each of the clay-mineral particles. These cations are not fixed on, but rather are held near the surface by electrostatic attraction, and they undergo thermal motions often likened to bees around a hive. These ions, which can be displaced by other ions in solution (i.e., "exchanged"), can only get as close and move as easily as permitted by their hydrated size. Ions with smaller hydrated size and with greater charge, such as the calcium ion, stay closer, on the average, than do larger hydrated monovalent ones such as sodium ions. In dilute solutions, therefore, the repulsion resulting from intermingling clouds of positive ions occurs when adjacent clay particles are closer to one another for small, multiply-charged ions on the clays than for large singly-charged ions. The van der Waals attraction can prevail in the former case and not prevail in the latter. Treating or leaching clay particles with dilute solutions of sodium or ammonium ions tends to disperse them, whereas dilute solutions of calcium, magnesium, or other multivalent metal ions tend to promote aggregation.
>
> The number of negative sites on the faces of clay minerals is roughly proportional to their surface area. An important factor is that the number of negative sites is limited. If the concentration of even large monovalent ions in the water surrounding the mineral particles becomes

sufficiently great, there will be little difference in the concentration of ions near the mineral surfaces and out in the solution. As a result, the Coulombic repulsion will not increase as particles approach one another, and the now dominant van der Waals attraction will result in cohesion.(3)

Thus, in a soil high in sodium relative to other ions, dilution can lead to clogging. Such soils are generally not used for septic tanks.

However, in a soil considered suitable for septic tank use, if the wastewater applied has a high concentration of sodium relative to total cation concentration, clogging can also occur, even though the original sodium concentration ratio indicated a suitable soil. A sodium concentration of fifty percent of the total (Ca, Mg, K, and Na) is the generally accepted critical point beyond which deflocculation by sodium becomes progressively greater.(3)

(2) Incompatibility of Applied and Aquifer Waters

Several reactions between applied wastewater constituents and substances in the soil solution can cause insoluble precipitates.

(a) alkaline earth materials (Ca, Ba, Sr, Mg) may produce insoluble carbonates, sulfates, orthophosphates, fluorides, and hydrozides.

(b) certain metals (Fe, Al, Cd, Zn, Mn, Cn) can form insoluble compounds with the same anions.

(c) certain oxidation-reduction reaction products can produce clogging.(3)

(3) Iron and Phosphate Coating of Particles

Iron or phosphate coating of soil particles occurs frequently in soils under aerobic conditions. The first phase of clogging occurs under aerobic conditions. Both phosphate and iron tend to accumulate during this phase, and iron continues accumulating during the second phase, while phosphate remains constant. It is possible that iron and phosphate accumulate as particle coatings which cause a reduction of the infiltration rate. Iron and phosphate may also be associated with organic matter that accumulates as a soil residue.(2)

BIOLOGICAL AND ORGANIC CLOGGING

Introduction

As mentioned earlier, microorganisms and organic matter appear to be the prime factors in soil clogging. The soil is very complex and extremely variable, but in general one can emphasize two points with regard to soil clogging: the importance of the relationship between the rates of production and destruction of clogging materials; and the importance of oxygen.

The soil is composed of five essential components, in the following approximate percentages, on a volume basis:

mineral materials	45%
solution*	25%

---

*Soil pore water with dissolved substances.

air	25%
organic materials	5%
biological populations	1%(7)

In undisturbed soils, the abundance of indigenous bacteria is not subject to marked fluctuations, and the organic matter content remains relatively constant; however, the system is dynamic, with the humus, or organic fraction, continually being turned over, i.e., being attacked by microbes and being reformed by microbes from the remains of land vegetation, with additions of carbon from land vegetation being balanced by losses of carbon through microbial respiration and CO_2 evolution. Some soil bacteria depend upon added organic substances and are usually scarce, but flourish when organic matter is added, only to decline in numbers when their food source is exhausted. When organic matter is broken down under completely anaerobic conditions, the degradation is incomplete, producing end products of higher energy content and fewer microbial cells than under aerobic conditions. It is also consistently slower under anaerobiosis than in the presence of adequate oxygen.(8) It also appears that some organic substances may not be degraded at all unless conditions are highly aerobic.

Septic tank effluent contains suspended and dissolved materials, both organic and inorganic; it may also contain bacteria. The content of such effluent, in conjunction with known soil processes, suggests a number of possible effects when effluent is applied to a soil surface:

(a) The solids themselves may get caught in soil pores, temporarily slowing infiltration. These solids will be attacked by microbes and degraded. However, this degradation will be slower in the absence than in the presence of oxygen.

(b) The increased amount of organic material, both dissolved and suspended, will stimulate the growth of bacteria. These bacterial cells themselves may, like the added solids, obstruct pore spaces, possibly leading to clogging. As long as sufficient food and oxygen are available, one can expect these bacterial populations to persist. If oxygen levels decrease, living aerobic bacteria may decrease; however, at low oxygen levels organic matter degradation is also decreased, and dead cells may accumulate. Also, at this point anaerobic organisms would be expected to increase.

(c) As bacteria degrade the added organic material, they will consume oxygen and produce breakdown products. From these breakdown products, other compounds may be synthesized. If oxygen is consumed more rapidly than it can be replaced by diffusion from the surface, oxygen tension in the soil may drop, possibly affecting the rate of degradation of certain substances which may depend on organisms only active in highly aerobic environments. These substances may accumulate and clog the soil. If sufficient rest is not allowed for reaeration, anaerobic conditions may result.

(d) If the soil environment becomes anaerobic, certain substances resulting from activities of anaerobic microbes may lead to severe soil clogging.

Soil Porosity and Clogging Mechanisms

Suspended Solids

In experiments with lysimeters containing either sterile or biologically active sand and subjected to continuous inundation with autoclaved (sterilized) sewage, Winneberger *et al.* demonstrated that suspended solids alone can produce significant clogging, but that such clogging is neither as great nor as rapid as that produced in an environment where microbial growth has not been prevented. Comparison of the infiltration rates suggested that, in both cases, filtration of sewage solids accounted for the initial rapid loss in infiltration rates.(1)

These authors also emphasize the importance of the size of the solids in the applied sewage. In experiments comparing septic tanks and aerobic units, the majority of solids from aerobic tanks were relatively large and flocculent. Such large solids were apparently less capable than smaller solids of clogging fine porous media, but more capable of clogging coarse porous media by bridging the large pores through which finer suspended matter easily flows. On the other hand, septic tank effluents contained many colloidal solids capable of clogging fine porous media.(1)

Thomas et al.(9) attributed clogging primarily to sewage solids:

> Particles of sewage solids form a clogged zone upon and a short distance beyond the interface. At the same time, biochemical decomposition and liquification is proceeding. Biological activity is accelerated with the concentration of organic material and the creation of large areas of contact surface. The biochemical processes of liquification and gasification lead to a progressive stabilization of organic solids, which tends to restore the perviousness (permeability) of the interfacial zone. This action is greatly speeded up if sufficient oxygen is available so that fairly complete aerobic decomposition occurs.

They emphasize the importance of the rate of degradation as opposed to addition and suggest that grain size or pore size, the principal factor measured by the percolation test (convection rates of fluids are markedly affected by grain size) may not be particularly relevant to oxygen diffusion which may, in reality, be the rate-limiting factor in the degradation of clogging materials; this is offered as a possible explanation of why the percolation test may not correlate with load capacity.(9)

Laak compared hydraulic load, total weight of BOD and suspended solids, and noncapillary porosity of the soil and found significant correlations. In experiments with several different soils, he found that the service time of a given soil surface was directly related to the sum of TSS (total suspended solids) and BOD in the load; and that a linear relationship existed between the sum of TSS and BOD in the failure load and the noncapillary porosity of the soil. Laak noted - as did Winneberger et al.(1) - that suspended solids in effluents from aerobic units were larger than those from anaerobic units. Laak also found that the failure load for anaerobically prepared liquid was consistently higher than that for aerobically prepared liquid. (However, aerobic effluents were generally sufficiently lower in TSS and BOD than anaerobic effluents that the clogging rate was reduced when aerobic units were used.)(10)

It would seem, therefore, that suspended solids are a significant factor in soil surface clogging, and that their reduction in applied wastewater would help alleviate the clogging problem. It further appears that, while it may not be of foremost importance in the overall problem, soil porosity, particularly in relation to the size of suspended solids in the applied liquid, is a factor in soil clogging.

Bacteria

Bacteria are recognized as elements in the clogging process, and the rest of this paper's discussion of clogging mechanisms is related to these microbes and their products as clogging agents. It is possible, however, that the actual bacterial bodies are principally responsible for clogging, and that aspect of microbial clogging is herein considered.

In Biological Aspects of Failure of Septic-Tank Percolation Systems,(1) Winneberger et al. list the rapid growth of aerobic organisms as prominent among factors tending to clog the soil. They contrast the clogging effects of more efficient conversion of organic matter into cell structures by aerobic than anaerobic organisms, occurring under more aerobic conditions, with the unclogging effects of the concurrently more rapid reduction of deposited solids by biodegradation, under the same conditions. However, they attribute clogging primarily to organic solids in general and to ferrous sulfide produced by anaerobic organisms.

Rein Laak removed the clogging layer from his lysimeters and examined the material between the sand grains. He found this material to consist 90% or more of bacterial cells, closely packed together. These bacteria included coliforms, fecal E. coli, and Pseudomonas, both in soils loaded with septic tank effluent and with extended aeration tank effluent. He suggests that the clogging rate is probably dependent upon the rate of substrate or soluble BOD conversion into organisms and their time of retention in the clogging zone.(10)

Gupta and Swartzendruber(11) examined bacterial numbers in soil continually saturated with boiled deionized water. They found that, up to concentrations of 400,000 bacteria/gram of sand, bacterial numbers had little effect on the infiltration rate, but that about this breakpoint the infiltration rate dropped sharply. However, according to calculations made by Gupta in his unpublished M.S. thesis, the critical numbers of 400,000 bacteria/gram of sand in the clogging area would occupy only 0.00031% of the total void volume of the sand in this area; from this he concludes that the direct causative effect of bacterial bodies is unlikely, unless they are strategically located at grain contacts throughout the area. This appears to contradict Laak's conclusions and, possibly, his results.

It seems likely that increased numbers of bacterial cells produced in the presence of large amounts of added organic material would physically contribute to clogging. However, clogging occurs in soils where no organic matter has been added to stimulate bacterial growth, and one wonders whether lowered oxygen and decreased degradation rates could be sufficient to cause accumulation of bacterial bodies to such an extent as to clog the soil. Gupta's experiment addressed such a situation and, while he found large bacterial increases (the source of energy for which he could only explain by the possible contamination of the deionized water with nitrogen, frequently the limiting factor in carbon assimilation, which might allow more of the soil carbon to be utilized), these increases did not appear to be sufficient to clog the soil severely. He suggests the possibility of clogging produced by by-products of microbial metabolism.(11)

Polysaccharides, Polyuronides, and Soil Aggregation

Polysaccharides and polyuronides appear to be the most important substances in soil clogging. They are defined as follows:

- Polysaccharide: a carbohydrate that can be hydrolyzed to many monosaccharide molecules (e.g., table sugar, starch, glycogen).
- Monosaccharide: a carbohydrate that cannot be hydrolyzed to simpler compounds (e.g., glucose, fructose).
- Carbohydrate: polyhydroxy aldehydes, polyhydroxy ketones, or compounds that can be hydrolyzed to them.(12)

- **Polyuronide:** polysaccharide containing uronic acid residues in greater or lesser quantities as part of the structure of the molecule.(8)

Polysaccharides include cellulose, the most abundant chemical constituent of higher plants. Polyuronides include some hemicelluloses, pectic materials, and plant gums. It is likely that polyuronide hemicelluloses do not occur in free form, but rather are intimately linked with other components of the cell wall of higher plants, possibly in the form of lignin-polysaccharide complexes.(8)

Polysaccharides and Polyuronides in Soil. Polysaccharides and polyuronides are commonly present in the soil, as part of the soil humus.(8) Besides occurring in plant materials which are normally added to the soil from overlying vegetation, they are produced by many microorganisms in the capsular or mucilaginous material that commonly surrounds the cells.(13) Pure polyuronides, such as pectin, are rapidly attacked by a wide range of organisms. However, certain uronic acid complexes appear to be more resistant to rapid decomposition than cellulose or the pentose groupings of the hemicelluloses. It is suggested that these uronide residues may be stabilized by association with some other grouping in the soil, probably an organic one.(13)

Experimental Evidence Regarding Clogging. In experiments by Mitchell and Nevo involving prolonged percolation in sand of water with high levels of organic matter, polysaccharide-producing organisms were found to predominate in the clogged layers, and a positive correlation was found between the accumulation of polysaccharides and polyuronides in the soil profile and clogging of the columns. (The correlation coefficient for total polysaccharides was 0.71, while that for the polyuronide fraction was 0.92.) The majority of the polysaccharide-producing organisms were strains of Flavobacterium. The polyuronides appeared more resistant to degradation, in that 1 day of drying produced an 85% decrease in the total polysaccharide concentration and only a 20% decrease in the polyuronide fraction. The authors noted that both microbial cells and the polysaccharides they produce can cause clogging, but that polysaccharides constituted the largest part of the clogging material.(14)

Avnimelech and Nevo emphasized the production rates vs. degradation rates of clogging material, and the importance of the stability of the clogging agent. Continuous inundation of sand with water containing materials with high C/N ratios (mostly starch) led to prolonged clogging, whereas treatment with materials with lower C/N ratios (casein) led to rapid but temporary declines in percolation rates. The correlation coefficient between polyuronide concentration and hydraulic conductivity in these cases was 0.9327.(15) It was suggested that, since it had previously been noted that uronic acid content of organically amended soil increased to a greater extent in the absence than in the presence of added nitrogen [G. Chesters - Ph.D. thesis, 1959, see (14)], perhaps the addition to soil of organic materials with high C/N ratios was associated with the production of larger quantities of polysaccharides with uronic acid residues and these were more resistant to degradation. This suggested that substrate governed the ratio of formation of stable to formation of unstable polysaccharides by Flavobacterium.(13)

Thomas, Schwartz, and Bendixen(2) compared changes in the concentrations of six chemical constituents in the soil - namely sulfide, phosphate, iron, total organic matter, polysaccharide, and polyuronide - with changes in the infiltration rate of septic tank effluent in lysimeters, during intermittent dosing and prolonged rest. Polysaccharides, polyuronides, and total organic matter all accumulated rapidly during the first phase of clogging and more slowly during the second. Polyuronide appeared to be directly associated with the accumulating organic matter, while total polysaccharide was not. During recovery of the infiltration rate during the rest period, polysaccharide and polyuronide concentrations remained constant while total organic matter declined.

The authors concluded that, while sulfide was probably not a primary cause of clogging, any one or all of the other five measured constituents may have contributed to the decline in phase I and phase II of the clogging process.

> They all accumulate in the layer of the soil that is becoming clogged, and they show a progressive accumulation throughout both phases. The mass of total organic matter present appeared to contribute significantly to clogging since the recovery of the infiltration rate was accompanied by a decrease in the concentration of total organic matter in the soil. The fact that the concentration of the four

remaining measured constituents did not change during the rest period does not exclude them as possible clogging agents. Changes in the physical properties as a result of drying could improve the infiltration rate without altering the concentration of a constituent. Irreversible dehydration of the polysaccharide is an example of a physical change which could have occurred undetected under the conditions of this study.(2)

Polysaccharide Accumulation. Clogging appears to be associated with polysaccharide and, particularly, polyuronide accumulation. It is also associated with decreasing pore oxygen. McGauhey and Krone discuss the existence of both polysaccharide-producing and polysaccharide-destroying organisms in the soil, with predominance of one or the other dependent upon environmental conditions. Both organisms grow over a wide range of temperature. Polysaccharide-destroying organisms are only active in the pH range of 7-9. The most interesting difference appears to be in oxygen requirements. There is some difference in opinion as to oxygen demands of polysaccharide producers: according to Mitchell and Nevo, no polysaccharides are produced in totally anaerobic conditions;(14) on the other hand, Allison states that both aerobic and anaerobic microorganisms synthesize aggregating gums, which are chiefly polysaccharides.(16) McGauhey and Krone emphasize the wide range of oxygen tension under which detectable amounts of polysaccharide were produced, stating that only under completely anaerobic conditions (about -400 mV) was inhibition observed.(3) On the other hand, the same two authors note that polysaccharide-destroying organisms are apparently active only under highly aerobic conditions (+500 mV or above). Allison confirms that only aerobes can decompose aggregating gums composed chiefly of polysaccharides.(16)

Soil Aggregation. Soil aggregation is important to the percolation of water through soil. To requote McGauhey and Krone,

> Movement of water through clayey soils at useful rates requires a physical arrangement of the mineral particles that provides pores which are large relative to clay mineral sizes. The formation and stability of aggregates of clay minerals, or of all size fractions present, requires cohesion of the particles under the prevailing physical, chemical, and biological conditions during use....If a clay soil is to be used for water treatment the stability of wet aggregates during use is important.(3)

Soil aggregation has been found to be favorably influenced by organic matter and microbial activity.(17)

Aggregate formation involves orientation of fine soil particles and bringing them so close together that physical forces between them hold them there firmly when allowed to dry. Aggregate stability concerns forces and conditions existing within and outside of the aggregate. The binding action must be sufficiently strong to hold the particles in such close proximity that they will not pull apart on wetting. In nature this is primarily accomplished by polysaccharides, breakdown products of humus, and numerous inorganic substances. Wetting and drying tends to disrupt aggregates.(16)

Microbial polysaccharides have widely different degrees of stability against decomposition in soils. Most polysaccharides are not very resistant to degradation, but some tend to persist. One explanation offered by Allison is that the resistant polysaccharides may be held inside of aggregates or tightly bound to clay minerals and thus protected against biological attack. He suggests that the amount of organic material resistant to microbial attack is proportional to surface areas of clay domains and that only when aggregates are broken down, by some means, can microbes attack this matter. It follows that in a well-aggregated and undisturbed soil where stability depends on polysaccharides, a steady-state condition should exist; most of the newly produced polysaccharides should rapidly decompose since they are largely unprotected in a soil already saturated with protected polysaccharides.(16)

One must remember, however, that such excess polysaccharides could not be degraded in the absence of oxygen, and would accumulate.

In experiments by Saini and MacLean, adsorption of a soil polysaccharide and filtration rates in Kaolinite (one of the major clay minerals) were varied by saturation of the soil with different cations. In a dispersed (i.e., not well-aggregated) system, filtration rates increased with successive addition of polysaccharides, and later decreased as addition continued. It is suggested that a segment rather than the whole polysaccharide molecule competed with solvent molecules for surface sites on the clay whereby a fraction of total segments was absorbed and remaining segments protruding from the interface were attached to a free surface of an adjacent particle. This led to an increase in stable aggregates when the system was completely dispersed to begin with. With successive additions of polysaccharide, the filtration rate increased to a peak. It is suggested at this point conditions were such that there was insufficient free surface for bridging or, possibly, that the extended segments interfered physically with one another. Filtration decreased from this point on.(18)

Summary of Polysaccharide Role in Soil Clogging.

(1) Polysaccharides are produced over a wide range of O_2 tension but degraded only in a highly aerobic atmosphere.

(2) Polysaccharides may aid in aggregation until all clay surface sites are filled or until physical interference prevents further bridging. Such polysaccharides are resistant to degradation. Uronic acid residues appear to be complexed, but probably with some organic substance, and in this state are resistant to degradation. Polysaccharides neither in such complexes nor protected by adsorption on aggregates will be rapidly degraded in the presence of sufficient oxygen. However, in low-oxygen concentrations or under anaerobic conditions, such polysaccharides will accumulate, forming sticky gums.

(3) Polysaccharide accumulation coincides with decreases in filtration rate.

(4) Wetting and drying tends to break up stable aggregates, exposing formerly protected polysaccharides to degradation, but also altering (possibly increasing?) the surface sites available to accumulated polysaccharides.

(5) Upon drying of a clogged system, infiltration rate increases while total organic matter decreases. Polysaccharide and polyuronide concentrations remain constant.

(6) Addition of organic matter leads to increased aggregation and improved percolation rates upon drying.

(7) Polysaccharides appear to be a prime agent in soil clogging. A possible explanation for their failure to decrease in concentration with drying and increased infiltration rates is the breaking up of existing aggregates and the inclusion of a greater amount of polysaccharides into aggregates where they are protected from degradation.

Ferrous Sulfide

Ferrous sulfide has been implicated as a possible cause of clogging by several investigators. In an experiment with lysimeters, Winneberger *et al.* identified FeS as a colloidal suspended material present in the zone of black soil typically found at the sewage soil interface of long-inundated systems. The ferrous sulfide was apparently produced spontaneously by the reaction of ferrous (Fe^{+2}) and Sulfide ($S^{=}$) ions, separately produced by anaerobic microorganisms which use sulfate and ferric ions as electron acceptors.$^{(1)}$ The reaction for the sulfate ion is as follows:

$$4H_2 + SO_4^{=} \rightarrow S^{=} + 4H_2O \tag{8}$$

Accumulation of FeS coincided with severe clogging, and rest and reaeration led to disappearance of the FeS and increased infiltration rates. Removal of the FeS with acid led to a rapid increase in infiltration rates, during which time the FeS disappeared, and then a somewhat slower increase, attributed to the slower attack of the acid on organic deposits. The authors attribute clogging to both organic matter and FeS.(1)

Other experiments have led to the conclusion that, rather than a cause of clogging, FeS is simply an indicator of the anaerobic conditions which increase clogging. Thomas, Schwartz, and Bendixen, in the experiment observing concentrations of six constituents referred to earlier, noted an increase in sulfide during the second phase of clogging; however, they found that while FeS was lost during the initial 48-hour period that the surface was rested and exposed to air, the infiltration rate was not affected by this loss of the sulfide.(2)

Laak found, upon calculating the maximum possible FeS produced from iron and sulfate concentrations measured in the clogged soil, that iron and sulfur were present in insufficient amounts for FeS to constitute a major cause of clogging.(10)

Mitchell and Nevo found in their system that FeS formation was dependent upon the addition of sulfide, and that clogging was less severe in the case of addition of Fe or S or both together with organic matter. They offered the explanation that perhaps when Fe and/or S is added, some organic material is used for the growth of sulfate and ferric-reducing microflora and thus less is available for the production of polysaccharides, which appear to be the principal clogging agent.(14)

Fine particles of FeS could certainly contribute to the clogging of a soil where the pore sizes had already been reduced by other materials. Sulfur and iron are important constituents of living matter, and their presence in food refuse and human waste products is unavoidable, as is their subsequent metabolic conversion by soil organisms. Thus, the formation of black ferrous sulfide deposits is probably the most reliable indicator of anaerobic conditions in biologic waste treatment systems. The experimental evidence suggests, however, that ferrous sulfide is not the principal cause of clogging of soil absorption systems.

CONCLUSIONS

The soil environment is complex and there are many factors involved in soil clogging. Some clogging occurs under both aerobic and anaerobic conditions, but most severe clogging appears when conditions of very low oxygen (or anaerobiosis) occur. It seems apparent that suspended matter, both organic and inorganic, is an important factor in initial decreases in infiltration rate. Coating of particles with iron and/or phosphate may cause pore size to decrease, interfering with water movement. Physical alterations of particle distributions, chemical precipitates, and aggregate dispersion by sodium ion may be involved in some cases.

The addition of organic matter in the applied wastewater stimulates the growth of bacteria. These bacteria may reach high numbers and may behave as particulates, decreasing pore size and interfering with passage of the wastewater. These organisms also consume pore oxygen as they degrade added organic material.

When infiltration rates decrease due to the above factors, and the system is not given sufficient rest for drainage and restoration of soil pore oxygen, oxygen levels in the soil will decrease over time. At decreased oxygen levels, degrading processes may proceed at slower rates and, in some cases, cease. This may lead to the accumulation of bacterial products, which may lead to severe clogging.

Polysaccharides, and particularly polyuronides, which are constituents of sticky gums and which are degraded in only very aerobic atmospheres, are the most likely substances involved in severe and prolonged soil clogging. Their accumulation has been correlated with decreased infiltration rates. Since total organic matter was consistently related to changes in infiltration rate, it is likely that other organic substances which tend to resist degradation (e.g., lignins, tannins, waxes) also interfere with infiltration of wastewater throughout the process. Dead microbial cells, decomposed only slowly in anaerobic atmospheres, probably are also a factor.

Ferrous sulfide, which accumulates in large amounts in some cases when the soil atmosphere becomes anaerobic, may be a clogging factor in some cases. However, it is more generally recognized as an indicator of conditions which may lead to severe clogging, rather than a cause in itself.

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APPENDIX B

BACTERIA AND CHEMICALS IN SOILS

APPENDIX B

BACTERIA AND CHEMICALS IN SOILS

Changes in water quality of pretreated sewage applied to soil systems can partially be described by the fate of bacteria, viruses and chemicals as they move through soil systems. In their extensive search of the literature on those subjects, McGauhey and Krone* note:

> Bacteria, being particulate matter, might be expected to be removed by sedimentation, entrapment, and absorption and so penetrate a soil to the limited degree observed in the case of finely divided ferrous sulfide. On the other hand, as living matter with enzyme systems such organisms might also be expected to exercise more control over their own destinies than do more inert particles. The literature, however, offers little evidence from which comparisons can be made largely because the movement of inert particles in small numbers has been studied less than that of bacteria. Results of experiments on travel of bacterial pollution range from laboratory studies with sand and soil columns to field observations in which little if any knowledge exists of the extent of channeling, variation in permeability, and other pertinent factors.
>
> Beginning in about 1950, more intensive studies of the movement of bacteria were undertaken in various parts of the world with the specific objective of determining the public health safety of groundwater recharge with sewage effluents. The historic work of A. M. Rawn and associates on test plots at Whittier and Azusa, California led to the conclusion that water of a bacterial quality suitable for drinking purposes can be obtained by passage through a minimum of 3 to 7 feet of surface soil even though it be quite coarse.

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*McGauhey and Krone. Soil Mantle as a Wastewater Treatment System, University of California, Berkeley, SERL Report No. 67-11, December 1967.

One of the most recent and thorough studies of reclamation of water from sewage effluents is the well-known Santee Project near San Diego, California. Although the project is most noted for its contribution to a knowledge of the behavior of viruses with percolating water, it produced significant data on the travel of bacteria as well. Effluent from an activated sludge-type secondary sewage treatment plant is given tertiary treatment in an oxidation pond. Pond effluent is pumped a distance of 7,300 feet to 6 percolation beds in parallel across a shallow stratum of sand and gravel confined in an old riverbed. The infiltered water moves down this confined channel a distance of 1,500 feet to an interceptor trench dug across the channel, passing enroute sampling wells located at 200 and 400 feet downstream from the percolation beds. Tracer studies showed the flow rate in the gravel to be about 200 feet in 2 days. Composite samples taken each day of a 10-day sampling period were analyzed for coliform bacteria, fecal coliform, and fecal streptococci with the results shown in Table B-I.

The conclusions are that most removal occurred within the first 200 feet of travel, with little further removal in the next 1,300 feet above the interceptor trench. Never-the-less, the data show an impressive removal of bacteria by a very coarse medium.

Investigation of the movement of bacteria introduced directly into groundwater existing in soil or in deeper aquifers has been reported. Results shown in Table B-II all pertain to travel of coliform organisms so introduced. Stiles and Crohurst noted in these studies a tendency for pollution to stay in the capillary fringe of groundwater when the water table lowered. Similar experience was reported by Hofman in Germany and Dyer and Bhaskaran in India.

More extensive data were reported by McGauhey and Krone in studies of pollution travel during direct recharge of a confined aquifer. Water degraded to 6, 10, 20 and 27 percent primary sewage was injected at rates varying from 3 to 14 gallons per minute per foot of aquifer. Coliform organisms and fecal streptococci were used as indicators of the travel of bacterial pollutants and plate counts made to check the total bacteria present. The major results, summarized in Table B-III show that in no instance did bacteria travel as far as 100 feet from the recharge well. Coliform and enterococci showed no difference in travel. Bacterial regression was observed as a clogging mat developed at the aquifer face in the well.

TABLE B-I

SUMMARY OF BACTERIOLOGICAL ANALYSES

(Coliform, Fecal Coliform, and Fecal Streptococci)
All results are MPN/100*ml

SAMPLING STATION	OXIDATION POND	200-FT WELL	400-FT WELL	INTERCEPTOR TRENCH
COLIFORM BACTERIA				
No. of Samples	29	29	29	28
Maximum	11 M[a]	3,300	35,000	22,000
Minimum	330,000	< 180	78	20
Median	1.1 M	780	2,800	560
FECAL COLIFORM				
No. of Samples	29	29	29	28
Maximum	1.3 M	200	3,300	110
Minimum	4,500	< 18	< 18	< 18
Median	210,000	< 180	< 180	< 18
FECAL STREPTOCOCCI				
No. of Samples	29	29	30	29
Maximum	490,000	54,000[b]	9,200[b]	230
Minimum	450	2	2	<1.8
Median	4,500	20	48	6.8

[a] M = million.

[b] Only one high result.

*MPN-Most probable number of particular organisms for which a test is specific, a measure of potential for transmission of water-borne disease, excepting viruses and toxins

Source: McGauhey and Krone p. 74.

TABLE B-II

SUMMARY OF DISTANCES OF TRAVEL OF BACTERIA REPORTED IN LITERATURE CITED

NATURE OF POLLUTION	POLLUTANT	OBSERVED DISTANCE OF TRAVEL	TIME OF TRAVEL
Sewage polluted trenches intersecting groundwater	Coliform bacteria	65 feet	27 weeks
Polluted trenches intersecting groundwater	Coliform bacteria Uranin	232 feet 450 feet	-- --
River water in abandoned wells	Intest. pathogens Tracer salts	800 feet 800 feet	17 hours 17 hours
Sewage in bored latrines intersecting groundwater	Coliform bacteria Anaerobic bacteria	10 feet 50 feet	
Sewage in bored latrines lines with fine soil	Coliform bacteria	10 feet	
Sewage in bored latrines intersecting groundwater	Coliform bacteria	35 feet	
Sewage in bored latrines intersecting groundwater	Coliform bacteria	80 ft; regressed 59 20 feet	
Coliform organisms introduced into soil	Coliform bacteria	50 meters	37 days
Sewage effluents on percolation beds	Coliform bacteria	400 feet	
Sewage effluent on percolation beds	Bacteria	150 feet	
Sewage polluted groundwater	Bacteria	A few meters	
Introduced bacteria	*Bacillus prodigiosus*	69 feet	9 days

Source: McGauhey and Krone, p. 71.

TABLE B-III

MPN OF COLIFORM ORGANISMS IN OBSERVATION WELLS DURING CONTINUOUS RECHARGE WITH AN AVERAGE OF 2.4×10^6 ORGANISMS PER 100 ml

DISTANCE FROM RECHARGE WELL FEET	MPN, 3rd DAY	MPN, 12th DAY	MPN, 32nd DAY
13 N	240	240,000	230
28 N	2,400	240	5
47 N	240	38	5
63 N	23	8.8	None
88 N	None	None	None
138 N	----	None	None
39 NE	2,400	240	8.8
45 NE	None	8.8	None
63 NE	None	38	None
106 NE	None	None	None
39 NW	2,400	240	2,300
45 NW	240	None	5
63 NW	None	2.2	8.8
13 E	24,000	24,000	8.8
50 E	240	5.0	None
13 W	23	None	2,300
50 W	23	> 240	2.2
13 S	95	2,400	230
63 S	None	None	9.4
100 S	23	5.0	None
188 S	None	None	None
192 S	None	None	None

Source: McGauhey and Krone, p. 76.

Fournelle, et al., reported a similar experiment with a dosing well extending 3 to 4 feet below a groundwater table near (5-6 feet) the ground surface. Bacterial contamination, as measured by enterococci, extended only 50 feet in a narrow path of travel, 1.5 to 4 feet wide.

Krone and McGauhey observed the growth of non-enteric bacteria in a sampling well 250 feet from the point of recharge. This was the result of the escape of undegraded dissolved organic matter beyond the biologically active clogging zone and its travel to the well with moving groundwater. The source of bacteria in the well was contamination by unsterile sampling equipment. A similar situation was observed by McKee et al. These observers noted the development of coliform concentrations of from 100 to 20,000/ml at depths up to 8 feet in a well-ripened test basin at the Whittier Narrows wastewater reclamation plant. The surface was spread with a chlorinated effluent having a low residual coliform content (190 per 100ml). These soil organisms proved to be aerobacter which were presumably present within the bed as it was laid down, feeding upon the substrate that escaped beyond any surface mat of organic growth.

Until quite recent years, little was to be found in the literature concerning the travel of viruses with percolating water. Nevertheless, the presence of viruses in sewage and their relation to epidemics of hepatitis has been so amply documented that the possibility of viral travel with percolating water is an important question in water quality management. In 1958, Weber reported an outbreak of hepatitis due to contamination of well waters by seepage of sewage effluent. The following year, Clarke and Change listed 5 epidemics of hepatitis, involving some 540 cases due to sewage polluted wells and springs, which occurred during the period 1944 to 1956. Bloom, et al., isolated 150 viruses in examining 1,018 sewage samples over a 20-month period. Of those not identified or lost on culture, 31 were identified as Echo, 4 as Polio, and 76 as Coxsackie. Several researchers have shown viruses to be more resistant to chlorine than are bacteria, thus making it more critical that their behavior in a soil system be explored.

Such an exploration was conducted in the Sante Project. In one experiment, twelve liters of concentrated Polio vaccine virus, Type 3, was mixed with 10 gallons of unchlorinated water and applied to the percolation bed influent over a period of 3 hours. Virus samples were then collected from the previously described sampling wells at 200 and 400 feet downstream and from the infiltration trench at 1,500 feet. All samples were found to be negative for polio virus, and it was concluded that the virus had been removed in less than 200 feet of flow through the gravel bed.

> Viral examinations of raw sewage, activated sludge effluent, oxidation pond effluent, and effluent from the percolation field were made over a period of some 3 years. Reovirus, Adenovirus, and several types of Polio, Echo, and Coxsackie viruses were identified at all times in all primary and secondary effluent; somewhat scattered in the oxidation pond effluent; and never found in the percolate from the soil system. Although the virus of hepatitis is known to be present in sewage, it is not subject to culture by currently known methods. There is, however, no reason to expect it to behave differently than other enteric viruses.

In summarizing their conclusions concerning removal of bacteria and viruses, these two authors conclude:

> Research findings from studies of the travel of bacterial and viral pollutants with percolating water and with groundwater in saturated aquifers reveal a number of facts of engineering importance. Among the most pertinent are:
>
> (a) Bacteria behave like other particulate matter in soils and are removed by straining, sedimentation, entrapment, and absorption. In addition, they are subject to die away in an unfavorable environment.
>
> (b) The ability of bacteria as living matter with enzyme systems to move more freely than inert particles has not been evaluated, since most research has utilized living particles as the test material.
>
> (c) Coliform and other bacteria have been observed to move but a few feet with percolating water in unsaturated flow and a few hundred feet in groundwater in saturated systems.
>
> (d) Intestinal pathogens may survive in soil for periods up to about 2 months, depending upon the organic content of the soil, and retain their virulence during the period of survival.
>
> (e) Viruses are removed by soil systems, probably principally by absorption, as effectively as are bacteria.

(f) It may be concluded that both biological antagonisms and physical removal of bacterial and viral cells characterize the change in biological quality of water percolating through a soil system; and that the system is a quite efficient device for removing such cells.

In discussing degradation of chemicals, McGauhey and Krone concentrate on chemicals found in industrial sewage but note,

> ...the increment of total dissolved solids added by domestic use of water is about 300 mg/ℓ. Of this total, of course, some may be degradable in the soil, depending upon the extent of pretreatment; but a considerable amount represents simply an increase in the cations and anions which may normally be found in groundwater and which are known to move with it. Thus, some increase in mineralization of groundwater is to be expected if wastewater is percolated through any soil system.
>
> ...At the Santee Project, high residuals of nitrates, phosphates, ammonia, and ABS appeared at the 200-foot sampling well. Samples taken at the interceptor trench after 1,500 feet of percolation, however, showed phosphorus, total nitrogen, COD, ammonia, and ABS to be totally removed. Total organic chemicals were not greatly reduced at 200 feet but were 75 per cent removed by 1,500 feet of percolation.
>
> Klein, et al., using S^{35}-labelled ABS applied to five California soils in small lysimeters, reported removals of only 20 to 30 per cent of applied ABS in 17-day experiments. In subsequent experiments extending over a much longer period these same investigators found ABS 80 percent degraded by a soil system after a 30-day period of acclimating of the system. More recently Klein and McGauhey in studying the degradation of detergents in septic tank percolation fields found ABS reductions of 55 to 74 percent. The softer detergent, LAS, was more than 97 percent degraded: and alcohol sulfate was almost totally destroyed (99.7 percent). All of these values were noted during passage through 2 feet of soil below the infiltrative surface.

The greater relative importance of biodegradation, rather than adsorption, as the mechanism of detergent removal was emphasized by Klein and McGauhey, who obtained removals of LAS and alcohol sulfate in excess of 97 per cent in both normally operated and deliberately overloaded septic tank percolation fields.

In summarizing their conclusions concerning the fate of some chemicals, McGauhey and Krone state:

> The ability of soil systems to remove chemicals from percolating water is quite limited. Biodegradable organic materials are normally attacked in the clogging zone and reduced to intermediate compounds and ultimately to stable compounds which characterize groundwater, e.g., nitrates, phosphates, carbonates, sulfates, etc. Concerning these and other ions which may come from industrial wastewaters, a number of important facts may be noted:
>
> (a) A considerable fraction of the 300 mg/ℓ total dissolved solids added to water by domestic use appear as anions and cations normally found in groundwater. Thus, an increase in the normal mineralization of groundwater is to be expected if wastewater is percolated through a soil system. Under normal conditions of soil pH, phosphates are effectively removed. Chlorides, sulfates, and nitrates, however, move quite freely with percolating water and situations have already developed where nitrate content has limited the use of sewage effluents for groundwater recharge...
>
> (b) ...Synthetic detergents can be effectively destroyed by biochemical degradation in a biologically active aerobic soil system in which there is no escape of partially degraded material from the biosystem.
>
> ...The foregoing findings refer, of course, to situations involving relatively bare soils. If the engineered system should make use of vegetation which is harvested, a considerable amount of nutrients may be taken up and so removed from percolating water.

> Particulate Matter
>
> Inert and organic particulate matter is effectively removed, usually by the top 5 or 6 inches of a soil system. Individual particles may penetrate further, but it is to be expected that a soil system will remove particulates from a wastewater. Clogging of the infiltrative surface rather than quality of the percolated water is the principal factor in relation to particles, with the possible exception of bacterial and viral cells which have the potential to multiply in the human body.

From the findings and citations of the above quoted authors and consideration of material in Chapter III, it is evident that there is considerable uncertainty, or at least diverse conclusions, among different authorities. In addition, it should be pointed out that soil conditions and resultant events are extremely variable within and between localities.

APPENDIX C

A SIMPLIFIED ECONOMIC AND ENVIRONMENTAL IMPACT MODEL OF THE DIFFUSION OF IMPROVED INDIVIDUAL WASTE TREATMENT SYSTEM TECHNOLOGY

APPENDIX C

A SIMPLIFIED ECONOMIC AND ENVIRONMENTAL IMPACT MODEL OF THE DIFFUSION OF IMPROVED INDIVIDUAL WASTE TREATMENT SYSTEM TECHNOLOGY

PURPOSE

This model is intended for providing insight into relative costs and some environmental impacts of alternative mixes of individual on-site domestic waste treatment systems and centralized public collection conveyance and treatment systems. In constructing the model, certain simplifying assumptions have been made in order to match the degree of detail examined with resources available for the conduct of this phase of the study. In addition, data selected for incorporation in the modeling effort are considered to be of a nature that would call for considerable refinement in other than a highly aggregated preliminary analysis.

The question under examination concerns the aggregate economic impact of providing new sewage service facilities to that portion of the population which will occupy new individual homes constructed in the 1970-1989 period. In particular, the resultant approximate total life cycle cost of such services is examined as a function of the time-evolving rate of utilization of individual home systems. A variety of assumptions as to the rate and magnitude of diffusion of individual home system technology are examined. Centralized collection, conveyance treatment, and disposal systems which provide secondary and selected tertiary levels of treatment are assumed to provide sewage service to those individual homes not using individual system technology. All systems are assumed to be newly constructed.

APPROACH

Figure C-I indicates the outlines of the approach selected. Starting with the series D census projection* of population growth to 1990, and utilizing a National Association of Homebuilders estimate of housing supply in the 1970-1980 period, a projection of new individual home construction is derived. Alternate projections and bases for projections clearly should be utilized as well but were not in this study.

Given this foundation, the rate and magnitude with which individual home system technology is incorporated in new individual home construction is treated as a process of specifiable proportions. The major parameters chosen to represent this process of technology diffusion are: the current rate of utilization of conventional individual home systems; the short-term projected rate of change of usage of these systems; the time it takes for new or improved individual systems to begin to be utilized in increasing proportions of new homes; the rate at which new or improved individual system technology continues to be used in increasing proportions; and the maximum rate of utilization of individual systems. This process is thus depicted as one of a delayed reaction to such technology, followed by a period of

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*U.S. Bureau of the Census, Population Estimates and Projections, Series p-25, No. 449, August 6, 1970.

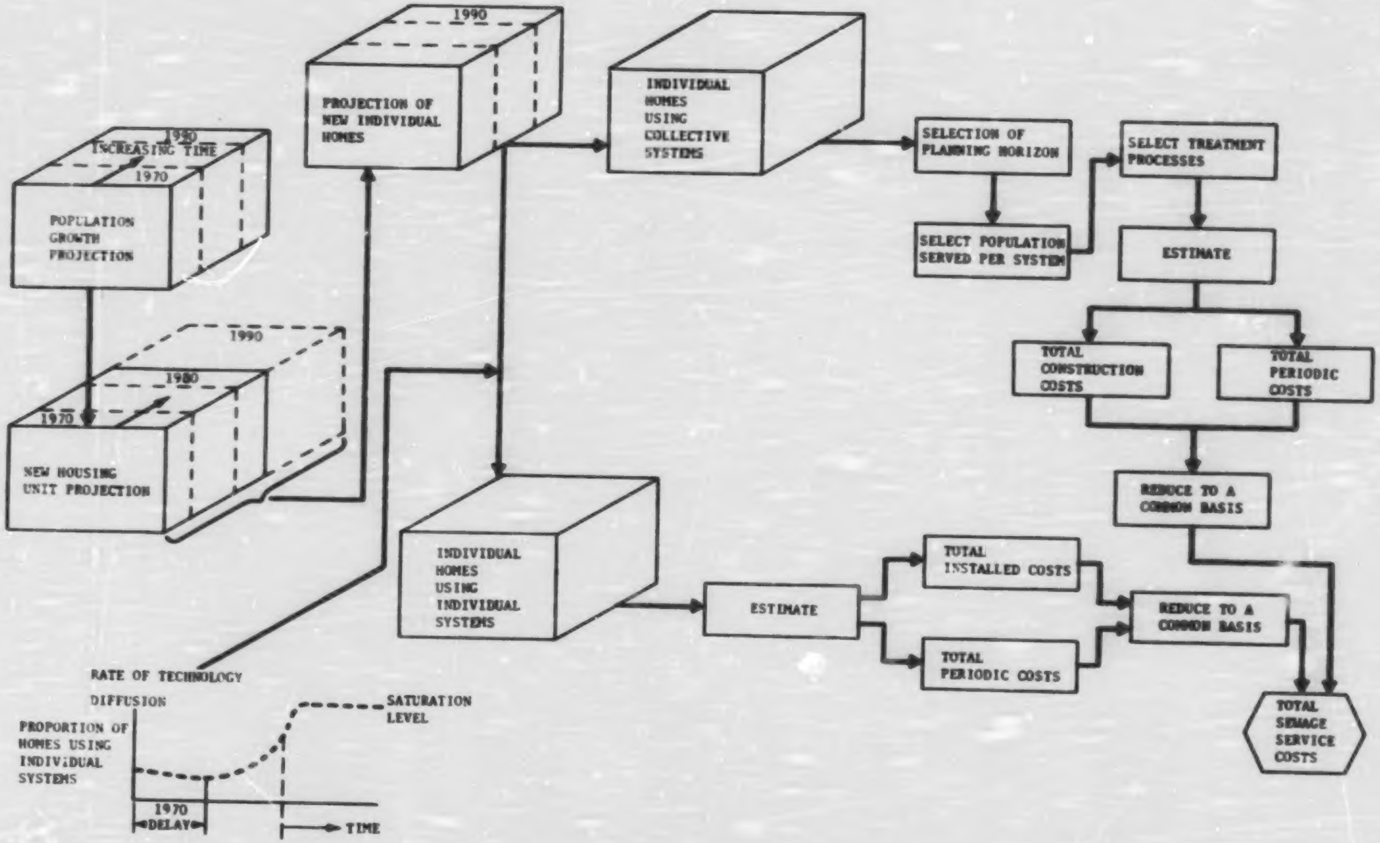
POPULATION GROWTH PROJECTION
INCREASING TIME
1970
1980
NEW HOUSING UNIT PROJECTION
1970
1980
1990
PROJECTION OF NEW INDIVIDUAL HOMES
1990
INDIVIDUAL HOMES USING COLLECTIVE SYSTEMS
INDIVIDUAL HOMES USING INDIVIDUAL SYSTEMS
RATE OF TECHNOLOGY DIFFUSION
PROPORTION OF HOMES USING INDIVIDUAL SYSTEMS
SATURATION LEVEL
1970
DELAY
TIME
SELECTION OF PLANNING HORIZON
SELECT POPULATION SERVED PER SYSTEM
SELECT TREATMENT PROCESSES
ESTIMATE
TOTAL CONSTRUCTION COSTS
TOTAL PERIODIC COSTS
REDUCE TO A COMMON BASIS
ESTIMATE
TOTAL INSTALLED COSTS
TOTAL PERIODIC COSTS
REDUCE TO A COMMON BASIS
TOTAL SEWAGE SERVICE COSTS

FIGURE C-1

COMPONENTS OF THE MODEL

increasing utilization at an accelerating rate, then followed by increasing utilization at a decreasing rate until a saturation level is reached.

That proportion of new individual homes not utilizing individual systems is assumed to be serviced by centralized systems. Two secondary treatment processes and several tertiary treatment processes and utilization patterns are considered. Under a variety of assumptions as to the average population each collective system will service, investment and periodic costs for these systems are approximated based on statistical cost studies. Individual system investment and periodic costs are also approximated. Thus, total costs of providing sewage services to new individual homes are derived as a function of the relative mix of individual and centralized systems under a variety of specifiable assumptions as to the nature of the assumed utilization pattern of individual systems.

COMPONENTS OF THE MODEL

Population Growth Projection

The basis for population growth projections was provided by The Bureau of the Census Series D projection contained in the August 6, 1971 publication "Current Population Reports, Population Estimates and Projections."

Housing Unit Projection

This projection is based on the 1970-1980 projection of housing supply of The National Association of Home Builders reproduced in

Table C-I. This projection is based in part, on the above population projection. Examination of the ratio of projected yearly housing supply and the net yearly change in population contained in the Series D forecast yielded the results contained in Table C-II.

Beyond 1980, the constant multiplier of 1.16 was used to convert net yearly population change to yearly rate of new housing unit construction. The results are shown in Table C-III.

Projections of New Individual Homes

New housing unit projections were converted to new individual home construction with the assistance of estimates of the split of apartment/individual home construction. These estimates were provided by the Economics Group of the National Association of Home Builders and are shown in Table C-III.

Projection of Individual Homes Using Individual Systems

The percentage of new individual homes utilizing individual systems technology each year during the time frame of interest is the quantity selected to indicate the magnitude of diffusion of individual system technology. The particular form chosen is a modified logistics curve.* The features of the logistics curve that make it attractive for this purpose are inclusion of a saturation level and an initial acceleration followed by a period of increase but at constantly decreasing rates. This curve has been modified to include a delay time before there is

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*Darracott et al. Report on Technological Forecasting, 1967, pp. 4:15-4:17, Clearinghouse for Federal Scientific and Technical Information.

TABLE C-I

ESTIMATE OF HOUSING REQUIREMENTS FOR THE 1970s

(Thousands of Units)

	DEMAND							SUPPLY				SURPLUS OR DEFICIT	
Year	(1) Net Increase in House holds	(2) Net Removals	(3) Net Removal of Mobile Homes	(4) Change in Vacancy	(5) Demand for Second Homes	(6) Total Annual Housing Demand	(7) Three Year Moving Average	(8) Housing Starts	(9) Mobile Home Shipments	(10) Total New Units	(11) Three Year Moving Average	(12) Annual	(13) Accumulation
1959	1,364	490	60	30	35	1,979		1,554	120	1,674		-305	-305
1960	665	510	63	30	40	1,308	1,722	1,296	104	1,400	1,510	92	-213
1961	1,188	530	66	51	45	1,880	1,480	1,365	90	1,455	1,488	-425	212
1962	537	550	66	49	50	1,252	1,563	1,492	118	1,610	1,619	358	-146
1963	807	570	67	58	55	1,557	1,612	1,642	150	1,792	1,718	235	89
1964	1,255	590	67	56	60	2,028	1,739	1,562	191	1,753	1,757	-275	-186
1965	841	610	66	51	65	1,633	1,738	1,510	217	1,727	1,631	94	-92
1966	753	630	65	36	70	1,554	1,870	1,196	217	1,413	1,567	-141	-233
1967	1,599	650	66	34	75	2,424	2,014	1,322	240	1,562	1,613	-862	-1,095
1968	1,206	670	70	39	80	2,065	2,205	1,548	318	1,866	1,769	-199	-1,299
1969	1,250	680	70	41	85	2,126	2,100	1,500	380	1,880	1,842	-246	-1,540
1970	1,222	690	70	38	90	2,110	2,063	1,400	380	1,780	1,893	-211	-1,751
1971	1,041	700	75	43	95	1,954	2,168	1,650	370	2,020	2,047	66	-1,685
1972	1,505	710	75	50	100	2,440	2,232	1,950	390	2,340	2,287	-100	-1,785
1973	1,338	720	80	54	110	2,302	2,375	2,100	400	2,500	2,470	198	-1,587
1974	1,383	740	80	60	120	2,383	2,385	2,150	420	2,570	2,570	187	-1,389
1975	1,430	750	100	61	130	2,471	2,468	2,200	440	2,640	2,640	169	-1,220
1976	1,478	770	100	62	140	2,550	2,554	2,250	460	2,710	2,710	160	-1,060
1977	1,530	780	120	60	150	2,640	2,406	2,300	480	2,780	2,780	140	-920
1978	897	790	120	61	160	2,029	2,628	2,350	500	2,850	2,850	822	-98
1979	2,055	810	120	62	170	3,217	2,621	2,400	520	2,920	2,920	-252	-350
1980	1,413	820	140	64	180	2,617		2,430	540	2,990		373	23

Source: (1) Derived by using person's per household from the Current Population Reports, P-25-394, page 18, Series D-1, 1976-1980, estimated by NAHB Economics Department and population projections as reported in the Current Population Reports, Series P-25, No.448, pp. 28-29, Series D.

(2) Annual estimates based on Demolitions and Other Factors in Housing Replacement Demand, M. Sumichrast & M. Farquhar, Homebuilding Press, 1967.

(3) Based upon an unpublished "scrap-out ratio" developed by Mr. Rickard A. Brickey, Marketing Research Manager, Research and Engineering Center, Whirlpool Corporation, 1970 to 1980 estimated by NAHB Economics Department.

(4) Estimated by NAHB Economics Department based upon continuation of current vacancy levels throughout the 1970's.as reported in the Current Housing Reports, Series H-111 Quarterly.

(5) Based upon current estimate of Bureau of the Census and Forest Service in "Second Homes in the United States", Current Housing Reports, H-121, No. 16; 1968 to 1980 estimated by NAHB Economics Department.

(6) Sum of columns (1) through (5).

(7) Three year moving average of column (6) centered on second year.

(8) 1959-1969, Bureau of Census, C-20, Housing Starts Report; 1970-1980, NAHB Economics Department Estimate.

(9) 1959-1969, Mobile Home Manufacturers Association; 1970-1980, estimated by NAHB Economics Department.

(10) Sum of columns (8) and (9).

(11) Three year moving average of column (10) centered on the second year.

(12) Column (10) minus column (6).

(13) Accumulation of the differences shown in column (12).

Source: National Association of Home-Builders, Economic News Notes, September 1970.

TABLE C-II

RATIO OF PROJECTED YEARLY HOUSING SUPPLY TO NET POPULATION INCREASE

YEAR	RATIO
1970	0.90
1971	0.90
1972	1.12
1973	1.16
1974	1.16
1975	1.16
1976	1.16
1977	1.16
1978	1.16
1979	1.16
1980	1.16

TABLE C-III

PROJECTION OF NEW INDIVIDUAL HOME CONSTRUCTION, 1970-1990

YEAR	U.S. POPULATION (000's)(1)	NET CHANGE (000's)(1)	TOTAL NEW HOUSING UNITS (000's)(2)	INDIVIDUAL HOMES (% OF TOTAL)(3)	INDIVIDUAL HOMES (000's)	CUMULATIVE NUMBER OF INDIVIDUAL HOME SINCE 1970 - (000's)
1970	205,167	1,970	1,780	55	980	980
1971	207,138	2,028	2,020	56	1,130	2,110
1972	209,166	2,084	2,340	56	1,310	3,420
1973	211,650	2,140	2,500	56	1,400	4,520
1974	213,390	2,198	2,570	58	1,490	6,310
1975	215,588	2,258	2,640	60	1,584	7,894
1976	217,845	2,318	2,710	60	1,625	9,519
1977	220,164	2,382	2,780	61	1,695	11,214
1978	222,545	2,448	2,850	61	1,740	12,954
1979	224,993	2,516	2,920	62	1,810	14,764
1980	227,510	2,583	2,990	62	1,855	16,619
1981	230,092	2,643	3,065	62	1,900	18,519
1982	232,736	2,695	3,125	62	1,940	20,459
1983	235,430	2,734	3,170	62	1,965	22,424
1984	238,164	2,761	3,200	62	1,985	24,409
1985	240,925	2,774	3,220	62	1,995	26,404
1986	243,699	2,776	3,220	62	1,995	28,399
1987	246,475	2,767	3,210	62	1,990	30,389
1988	249,242	2,750	3,190	62	1,975	32,364
1989	251,942	2,728	3,165	62	1,960	34,324
1990	254,720	2,701	3,135	62	1,945	36,269

(1) Source: Current Population Reports, Population Estimates and Projections, U. S. Department of Commerce, Bureau of the Census, Series p-25 No. 448, August 1970, Series D. p.9.

(2) Source: "Estimates of Housing Requirements for the 1970's," Economic News Notes, National Association of Home Builders, Washington,D.C. September 1970 provides this information to 1980. 1980-1990 projections derived by multiplying net population change by 1.16 (See Attached comments).

(3) Source: Rough Estimate provided by Mr. Buck, Economics Department, National Association of Home Builders.

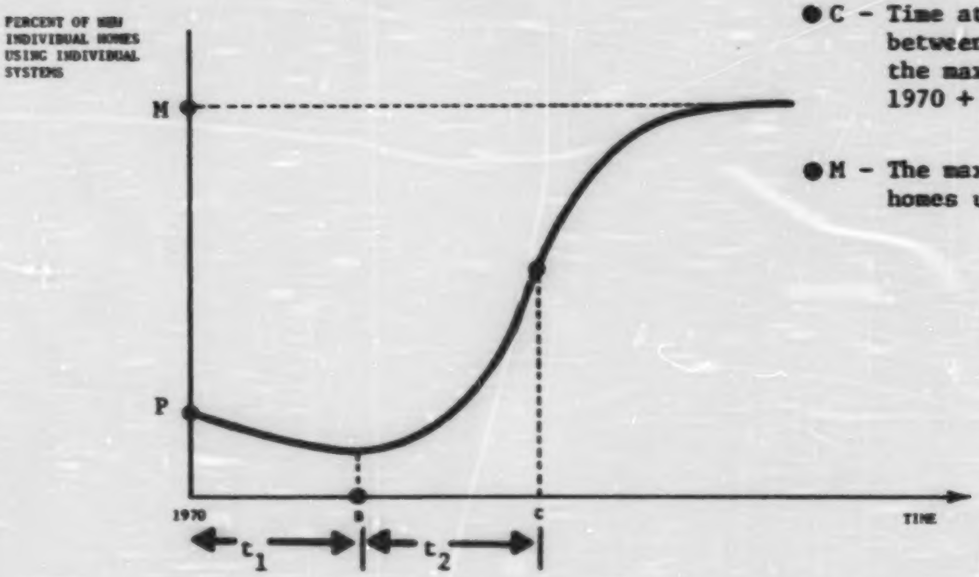
an onset of technological diffusion and to provide a decreasing rate of individual system utilization preceding the completion of the specified delay time. Figure C-2 indicates the general features of this chosen form of relationship, Figure C-3 indicates the mathematics utilized to generate the projections of the number of newly constructed individual homes utilizing individual and collective systems each year.

Cost Components of the Model - Collective Systems

Cost relationships utilized in arriving at estimates of the total cost of collective systems were obtained from the following sources:

> Robert L. Michel, "Construction Costs of Municipal Wastewater Treatment Plants, 1967-1969" Unpublished paper, May 1970 draft furnished by the Division of Facilities Construction and Operation, Federal Water Quality Administration. (Denoted M-1)
>
> Robert L. Michel, "Factors Affecting Construction Cost of Municipal Sewer Projects," Unpublished paper, August 1970 draft, same source (Denoted M-2)
>
> Robert L. Michel, "Costs and Manpower for Municipal Wastewater Treatment Plant Operation and Maintenance," Journal Water Pollution Control Federation, November 1970. (Denoted M-3)
>
> Robert Smith and Richard G. Eilers, "Cost to the Consumer of Collecting and Treating Wastewater in the United States," July 1970 preliminary copy, U.S. Department of the Interior, Federal Water Quality Administration, Advanced Waste Treatment Branch, Division of Research, Cincinnati, Ohio.

Because some of these papers are unpublished and are derived from very recent operating experience, the authors wish to express their deep gratitude to these individuals and their organizations. The manner in which the contents of these papers were selected and used here is the



- ● P - Percent of new homes using individual system in 1970
- ● B - Time at which new individual system technology begins to diffuse = 1970 + t_1
- ● C - Time at which one half the difference between the rate of diffusion at B and the maximum rate of diffusion is achieved= 1970 + t_1 + t_2
- ● M - The maximum percent of newly constructed homes utilizing individual systems

FIGURE C-2

FORM OF TECHNOLOGY DIFFUSION UTILIZED

PROGRAM

Input: TNHU(t) = Total new housing units (000s) in year t

Calculate: PIH(t) = Percent individual homes in year t (≤ 1.0)

Calculate: NIH(t) = TNHU(t)* PIH(t) (000s), New individual homes

CNIH(t) = $\sum_{1970}^{t}$ NIH(t), Cumulative number of new individual homes

Input: P(1970) = Percent of new individual homes using individual systems in 1970

t_1 = Year of beginning of technology diffusion

Calculate:

$$P(t) = \frac{P(1970)}{1 + (t - 1970)(0.1)} \quad t \le t_1$$

Percent of individual homes using individual units in years before t_1

Input: t_2 = Year of achieving half increment between utilization in year t_1 and maximum percent utilization

M = Maximum percent PCIU(t) can achieve

Calculate: DELP = $M - P(t_1)$ (must be ≥ 0)

The difference between usage in year t_1 and maximum usage

$$P(t) = \frac{P(t_1) + DELP}{1 + \frac{DELP}{P(t_1)} \exp. \left[-b(t - t_1)\right]} \quad t > t_1$$

$$\text{where } b = \frac{1}{t_2} \quad \text{Ln} \quad \left[2 + \frac{DELP}{P(t_1)}\right]$$

Calculate: NIHIU(t) = P(t)* NIH(t) New individual homes with individual systems in year t

CNIHIU(t) = $\sum_{1970}^{t}$ NIHIU(t) Cumulative new individual homes with individual systems in year t

Calculate: NIHCS(t) = NIH(t) - NIHIU(t) New individual homes using collective systems in year t

CNIHCS(t) = $\sum_{1970}^{t}$ NIHCS(t) Cumulative new individual homes using collective systems in year t

FIGURE C-3

MATHEMATICS UTILIZED IN PROJECTING NUMBER OF INDIVIDUAL HOMES USING INDIVIDUAL AND COLLECTIVE SYSTEMS IN THE 1970-1990 PERIOD sole responsibility of the author of this report and does not imply the concurrence of the originators or their organizations in the way the information is used or in the explicity or implicit interpretations this author places on it.

The previous section described the techniques utilized to generate a time-dependent estimate of individual homes utilizing collective systems. In order to convert this estimate to projected need for such systems, two major parameters must be fixed. First is the average number of persons per individual home, and second is the planning horizon utilized in construction of such facilities.

The average number of persons per housing unit has been steadily decreasing since 1790. Preliminary estimates for 1970 census figures indicate a 39-state average of 2.92 persons per housing unit.* However, such estimates are averaged over single and multiple dwelling units. An average of 3.5 persons per individual home is assumed throughout the remainder of this discussion, but provision is made for use of other assumptions in the computer model utilized.

The importance of the planning horizon relates to the future projected population that facilities under current construction will be sized for. Considerable questions as to the optimum tradeoff between flexibility of plant, excess capacity, and the uncertainties of detailed population projections underly this issue. However, in the remainder of this discussion of collective systems, facilities are sized according to 1989 population projections.

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*Economic News Notes, September 1970, National Association of Home Builders, Washington, D.C.

In addition to the above assumptions, it is necessary to assume an average value for the estimated design population serviced by a single collective system. To a large extent, this choice is dictated by availability of cost data in corresponding population ranges. A distribution of design population estimates would be preferable to an assumption of a uniform average value. However, for illustrative purposes only, design populations of 10,000, 25,000, 50,000, and 100,000 persons are chosen.

The cost components considered are as follows:

Construction Costs

- Treatment plants
  - Activated sludge plants
  - Trickling filter plants
  - Selected tertiary treatment process
- Ancillary works (interceptors, force mains, out falls and lift stations)
- Municipal collection systems
- House connections to municipal collection systems

Periodic Expenses

- Treatment plant operation and maintenance expenses
- Sewer operation and maintenance expenses
- Customer service and accounting expenses
- General and administrative expenses

Treatment Plant Construction Costs

Based upon Michel's examination (M-1) of 360 federal grant assisted projects completed or placed under construction in the January 1967 to April 1969 period expected values* of construction costs, expressed in terms of 1957-1959 based year costs, were converted to October 1970 costs through use of the Federal Water Quality Administration's Construction Cost Index. It should be noted that in the October 1969 through October 1970 period, the treatment plant component of this index rose by nine percent and in the preceding year, rose by seven percent. Inclusion of future cost growth in calculations is discussed later.

The resulting construction cost expressions are:

Activated sludge treatment plants:

$$Y_{TP} = 1.481 \text{ X Log}^{-1} [2.869 - 0.309 \text{ Lox X}]$$

High rate trickling filter treatment plants:

$$Y_{TP} = 1.481 \text{ X Log}^{-1} [2.883 - 0.8103 \text{ Log X}]$$

In these expressions, Y_{TP} is the expected value of treatment plant construction costs for a single plant as of October 1970. X is the population the plant has been designed to serve, which is definitely not synonomous with population served at a point in time. For this reason, per capita costs are not calculated at this point.

---

*Significant variations above and below the expected value do occur. These variations depend upon design capacity and can run up to ± 80-100 percent.

Based upon the work of Smith and Eilers, the additional construction costs of selected tertiary treatment processes, adjusted to an October 1970 basis are:

Microscreening:

$$Y_{TP} = 10.86\ X^{.881}$$

Filtration:

$$Y_{TP} = 240.24\ X^{.66}$$

Two-Stage Lime Clarification:*

$$Y_{TP} = 163.40\ X^{.74}$$

Lime Recalcination:

$$Y_{TP} = 2207\ X^{.5}$$

Ammonia Stripping:

$$Y_{TP} = 26.34\ X^{0.9}$$

Carbon Absorption:*

$$Y_{TP} = 88.17\ X^{.86}$$

OTHER CONSTRUCTION COSTS

The above cost relates only to construction of selected treatment facilities. In addition, the physical systems that carry waste water from the home to the plant must be considered. These costs are extremely sensitive to the specific topography, geology, climate, labor rates and delivered material costs for a specific location, as well as the detailed design specifications of the particular installation.

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*For plants with design capacity less than 10 million gallons per day, which is equivalent to a design population of 100,000 if average per capita sewage generation of 100 gallons per capita per day is assumed.

For example, Michel (M-3) cites several special conditions which typically raise installed costs per foot of 8 to 21 inch diameter piping by a factor of ten above installation costs under ordinary conditions.

The following nontreatment construction costs involve the listed facilities:

(a) Ancillary works - interceptor sewers, lift stations, outfalls and other items exclusive of municipal collection systems

(b) Municipal collection sewers

(c) Sewer connections from homes to collection sewers

Based upon the work of Michel (M-2) the following relationships are chosen:

Ancillary works connecting to activated sludge plants:

$$Y_A = 1.481 \text{ Log}^{-1} [1.843 + 0.911 \text{ Log } X]$$

Ancillary work connecting to trickling filter plants:

$$Y_A = 1.481 \text{ Log}^{-1} [2.3288 + 0.7832 \text{ Log } X]$$

where Y_A is the expected value of construction cost of ancillary works adjusted to October 1970 levels and X is the design population of the system.

Variations of a factor of two above and below these expected values are not untypical.

The costs of municipal collection sewer systems are difficult to estimate in general due to a sensitive dependence on local community land use patterns as reflected in average population density per acre and community layout patterns. The approximation utilized in this effort, which is recognized as requiring detailed modification when applied to a specific situation, is derived from an American Public Works Association unpublished study cited by Smith and Eilers. Sanitary sewer installation costs for a city of 100,000 population and an average population density of 8.3 persons per acre including house connections and man holes was quoted at $258.96 per capita. Smith and Eiler, using the 1968 sewered population as a base, conclude that average the per capita construction cost of municipal sewers was $157.82. If the American Public Works Association per capita house connection costs, $81.51, is added to this figure, a new figure of about $240 per capits results. This latter estimate is based upon a mix of population served which includes large metropolitan areas. The relationship utilized for construction costs of municipal sewers and house connections per plant is

$$Y_s = 260 X$$

where Y_s is construction cost in dollars on a 1970 basis and X is the design population

Periodic Costs

In addition to the above capital investment costs, collective systems incur periodic expenses associated with operation and maintenance (O and M) of treatment works and sewer systems. The following O and M expenses are based on Michel's work (M-3) and the tertiary treatment O and M, sewer maintenance, customer service and accounting, and general and administrative expenses are taken from Smith and Eiler.

Treatment Plant Operation and Maintenance Expenses

The components of treatment plant O and M expenses include salary and wages, electricity, chemicals and other supplies, and sludge handling and disposal operations. The data used were derived from examination of 1,600 treatment plants during the period from January 1965 through June 1968.

The plants entering this sample form an inhomogenous grouping of prevalent wage rates, age of plants, percent of design capacities utilized, number of degree of training of plant operators, and managerial efficiency. For this reason expected value results may not be typical of any one installation but should be representative of current operating conditions in general. Michel estimates probable errors of ±30 percent in these order-of-magnitude estimates.

In order to present these expenses on a current basis, it is necessary to correct for rapidly increasing O and M costs. For example, O and M costs increased rapidly in the 1960's, rising by a factor of two for million-gallon-per-day high-rate trickling filter treatment plants and a factor of 60 percent for activated sludge plants.* This increase is due to not only rising labor rates, but also increased community awareness of the need for more labor in order to maintain efficient and high-quality treatment operations. Based on preliminary data,** Michel's basic O and M costs for activated sludge and trickling filter plants are increased by 36 and 60 percent respectively to adjust to fiscal year 1969-70 cost levels. These figures represent the percentage increase, at the 1 million gallon per day average daily flow level of the respective O and M costs between the fiscal years 1966-1968 and fiscal year 1969-1970 periods. Based on these factors, the following expected value relationships are utilized:

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*Engineering New Record, December 17, 1970, pp. 52-57.

***Ibid.*

Activated sludge plants:

$$Z_{O\ \&\ M} = 1.36 \text{ Log}^{-1} [1.4505 + .7537 \text{ Log } X']$$

Trickling filter plants:

$$Z_{O\ \&\ M} = 1.6 \text{ Log}^{-1} [1.7904 + .6431 \text{ Log } X']$$

where $Z_{O\ \&\ M}$ are per plant O and M costs per year and X' is the population served by the plant in a given year. Note that O and M costs are based upon population served not design population.

O and M costs for selected tertiary treatment processes are based on estimates of Smith and Eilers. These expenses are left on a 1968 basis due to lack of availability fo cost growth figures. The relationships used are as follows:

Microscreening:

$$Z' = 0.30\ X'^{(.956)}$$

Filtration:

$$Z' = 51.31\ X'^{(.62)}$$

Two stage lime clarification:*

$Z' = 148.61\ X'^{(.56)}$

Lime recalcination

$Z' = 30.01\ X'^{(.70)}$

Ammonia stripping:*

$Z' = 35.49\ X'^{(.667)}$

Carbon absorption:*

$Z' = 1418.94\ X'^{(.45)}$

OTHER PERIODIC EXPENSES

Based on information in Smith and Eilers paper, the following expression is used to approximate sewer maintenance, customer service and accounting, and general and administrative expenses.

$$Z'_{\text{other}} = 2.94\ X'$$

REDUCTION TO A COMMON COST BASIS

A common basis of cost comparison is required in order to make meaningful comparisons among the total costs of providing waste water treatment to the population considered in this preliminary model under a variety of assumptions as to usage of individual and collective systems. Two general approaches are available: the present value of future costs approach and the continuous cash flow treatment of incurred costs.

The present-value approach requires a laying out of all costs over time. This time stream of costs is then discounted back to present value using a discount factor that represents, for example, alternative earning power of the funds involved. A typical example of the present-value approach is the equation of one dollar in hand today to two dollars in hand in one year with surety if in the interim period a guaranteed investment that will double in one year is available.

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*For plants with less than 10 million gallon per day average flow.

In performing present-value calculations, a complete time stream of events is required up to the point in time at which the effects of discounting reduce expenditures beyond this point to relative insignificance. This point in time will depend upon both the discount rate used and the magnitude of expenditures involved. For example, sharply peaked expenditures, such as replacement costs for major treatment works, even if occurring at distant points in time, can have significant impact upon the present value of future costs.

The continuous cash flow approach generates a time stream of expenditures by spreading "lumpy" costs, such as treatment work construction costs, over the life of the "lumpy" asset. This is accomplished by assuming annualization of lumpy costs and this associated debt service fees (interest payments) into constant annual expenditures. Periodic recurring expenses are added to these annualized costs to generate the total time stream of expenditures. A major attraction of this approach occurs when periodic expenses are constant in each year, since a single constant annual expenditure characterizes the total time stream of expenditures. However, if more than single lump-sum investments are made at various points in time, the situation postulated for individual systems, a time varying flow of annualized investment costs will result. Thus, with these combinations of events, a continuous cash flow basis would be characterized by as many numbers as there are years to include in the planning period.

Centralized Systems Common Cost Basis

To avoid these difficulties, and in order to provide a single, easily communicated measure of system costs, the present value approach is adopted with the following assumptions:

Let C_o^s = Total investment cost of ancillary works and sewers (on a 1970 basis) assumed to be needed to serve the population projected on collective system

C_o^T = Total investment cost of treatment works (1970 basis) needed to serve the collective system population

H = Planning horizon, chosen as 20 years.

H_s = Economic life of ancillary and sewer assets (50 yrs.)

H_t = Economic life of treatment assets (25 yrs.)

Pe^T = Periodic expenses of treatment (1970 basis)

Pe^o = Other periodic expenses (1970 basis)

i = Discount factor utilized

Then the present value of the costs of providing service to the portion of the population on collective systems, PVcs, is given by:

$$\begin{aligned} PVcs &= C_o^s + C_o^T && (1) \\ &+ \sum_{t=o}^{H} \frac{Pe^t(t) + Pe^o(t)}{(1+i)^t} && (2) \\ &- \left[\left(\frac{Hs - H}{Hs} \right) \frac{Co^s}{(1+i)^H} \right] && (3) \\ &- \left[\left(\frac{Ht - H}{Ht} \right) \frac{Co^t}{(1+i)^H} \right] && (4) \end{aligned}$$

The interpretation of each of the four terms is:

Term (1) - The total fixed capital investment of facilities designed for a population loading at the time horizon, H, at 1970 levels. Although this term places all investment costs in the first year of the planning period, this is not as bad as it appears. Realistically, system construction will take place over a period of time. However, the costs will rise over this time period. To the extent that such specific inflationary forces follow recent patterns, these cost increases will exceed the rate of increase of general inflationary forces as well as the rate of increase of the discount factor i. Discounting future rising outlays back to 1970 present values, using the factor i, will probably yield a result higher than term (1). Therefore, term (1) is probably conservative in that there is a probable underestimate of the present value of capital investment.

Term (2) - The present value of future periodic expenses up to the planning horizon H.

Term (3) - The "salvage value" of the postplanning horizon remaining economic life of ancillary and sewer assets, based on 1970 investment costs, prorated linearly over the economic life of ancillary and sewer assets and discounted to present value.

Term (4) - The same as term (3) but for treatment plants.

Individual System Common Cost Basis

A present-value approach is utilized for individual systems. Basically, the number of new homes utilizing individual systems each year is multiplied by the assumed total installation cost of each system, and this stream of investment is discounted to present value [term (5) below]. In addition, the cumulative number of individual systems in use each year is multiplied by the assumed annual periodic expenses associated with each unit, and this stream of periodic expenditures discounted to present value (term 2 below). Finally, since the economic life of some individual systems installed later during the planning period may exceed the planning horizon, the discounted individual system "salvage value" at the end of the planning horizon is subtracted from the above factors (term 7 below). Using the notation of Figure C-III, the present value of the costs of providing service to the portion of the population on individual systems, PV_{IS}, is given by:

$$PV_{IS} = \sum_{t=o}^{H} \frac{NIHIU(t) \cdot U(t)}{(1+d)^t} \qquad (5)$$

$$+ \sum_{t=o}^{H} \frac{CNIHIU(t) \cdot pe^{(is)}(t)}{(1+d)^t} \qquad (6)$$

$$- \frac{1}{(1+d)^H} \sum_{t=o}^{H} \overset{\boxed{\text{if } t+L-H \geq 0}}{NIHIU(t) \cdot U(t) \cdot \frac{(t+L-H)}{L}} \qquad (7)$$

$$+ \sum_{t=o}^{H} \overset{\boxed{\text{if } t+L-H < 0}}{NIHIU(t) \cdot U(t) \cdot \left[\sum_{k=1}^{I} \frac{1}{(1+d)^{t+kL}} \quad (I-X) \frac{1}{(1+d)^H} \right]} \qquad (8)$$

where

NIHIU(t) = The number of individual homes using individual systems in year t

U(t) = Unit cost of an individual system in year t

d = Discount factor utilized

H = Planning horizon (20 years)

CNIHIU(t) = The cumulative number of homes using individual systems in year t

$pe^{is}(t)$ = Periodic expenses per unit in year t

L = Individual system economic life

It should be noted that the third "salvage value" term accounts for individual systems installed in year t with lifetime L that reaches beyond the planning horizon. However, if this is not the case and the lifetime, L, of the individual system is such that the planning horizon is not reached, at lease one replacement of such systems is required. The fourth term calculates the number of replacement systems needed and discounts their future costs to present value. In this fourth term, the variables are:

$$X = \frac{H-t-L}{L}$$

the fractional number of replacement systems needed to reach the time horizon, and I is the nearest integer greater than or equal to X.

CALCULATION OF REDUCTION IN SURFACE STREAM BOD LOADING

The reduction in BOD loading of surface streams that occurs through use of individual systems as opposed to use of centralized facilities may be calculated by:

$$\Delta BOD(t) = P(t)(1 - r)(\frac{1}{6})\ 365$$

where $\Delta BOD(t)$ is the number of pounds of BOD per year that would have entered surface streams in year t if centralized rather than individual systems were used.

$P(t)$ = the population using individual system in year t

r = the percentage reduction in centrally treated raw sewage (values of 85, 90, and 95 percent are assumed)

This calculation assumes per capita daily generation of 1/6 lb of BOD for domestic sewage. The quantity $\Delta BOD(t)$ will be a function of the pattern of individual system technology diffusion assumed.

CALCULATION OF TREATED WASTEWATER RETURNED TO SOILS AND GROUNDWATERS

Individual systems using soil disposal techniques return treated wastewater to the soils and ground waters. This may be calculated by:

$$R(t) = P(t)g(t)\ 365$$

where

$R(t)$ = the number of gallons of domestic wastewater returned to soils and groundwaters per year

$P(t)$ = the population using individual systems in year t

$g(t)$ = per capita daily domestic water consumption (values of 80, 100, and 120 gallon per capita per day are assumed)

$R(t)$ will be a function of the pattern of individual systems technology diffusion assumed.

APPENDIX D

OUTPUT OF MITRE ECONOMIC AND ENVIRONMENTAL IMPACT MODEL

FOREWORD

This Appendix contains selected output which resulted from the use of the MITRE Economic and Environmental Impact Model. The model was exercised for many more combinations of parameter values than are included herein, and output not reproduced herein can be made available to interested parties. The results have been summarized and discussed in Chapter IV of the main report.

APPENDIX D

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II

SUMMARY PRINTOUTS OF SYSTEM COSTS

		Systems Using Septic Tanks After t_1				Systems Using Aerobic Tanks After t_1			
		Average Use of Each Tertiary Treatment Type				Average Use of Each Tertiary Treatment Type			
		None	16.6%	50%	100%	None	16.6%	50%	100%
t_1=50 (base case)		D26	D27	D28	D29	D26	D27	D28	D29
t_1=5; t_2=5	M=.25	D30	D31	D32	D33	D54	D55	D56	D57
	M=.33	D34	D35	D36	D37	D58	D59	D60	D61
	M=.40	D38	D39	D40	D41	D62	D63	D64	D65
t_1=5; t_2=10	M=.25	D42	D43	D44	D45	D66	D67	D68	D69
	M=.33	D46	D47	D48	D49	D70	D71	D72	D73
	M=.40	D50	D51	D52	D53	D74	D75	D76	D77

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1. M = .25 D-83
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I. SELECTED DETAILED PRINTOUTS OF DEMAND AND COSTS FOR INDIVIDUAL AND CENTRAL SYSTEMS

A. Base Case, t_1 = 50 years

```
                    PROJECTED  DEMAND  FOR
                  INDIVIDUAL  AND  CENTRAL
                     SEWAGE  SYSTEMS

        POPULATION  IN      THOSE  SERVED  BY     THOSE  SERVED  BY
      INDIVIDUAL  HOMES    INDIVIDUAL  SYSTEMS    CENTRAL  SYSTEMS
         (THOUSANDS)           (THOUSANDS)           (THOUSANDS)
YEAR  INCREMENT  CUMULATIVE INCREMENT  CUMULATIVE INCREMENT  CUMULATIVE
1970     3426.       3426.     514.         514.     2913.        2913.
1971     3959.       7386.     540.        1054.     3419.        6332.
1972     4586.      11972.     573.        1627.     4013.       10345.
1973     4900.      16872.     565.        2193.     4335.       14680.
1974     5217.      22089.     559.        2752.     4658.       19338.
1975     5544.      27633.     554.        3306.     4990.       24327.
1976     5691.      33324.     534.        3839.     5157.       29485.
1977     5935.      39259.     524.        4363.     5412.       34896.
1978     6085.      45344.     507.        4870.     5578.       40474.
1979     6336.      51681.     500.        5370.     5836.       46310.
1980     6488.      58169.     487.        5857.     6002.       52312.
1981     6651.      64820.     475.        6332.     6176.       58488.
1982     6781.      71601.     462.        6795.     6319.       64807.
1983     6879.      78480.     449.        7243.     6430.       71237.
1984     6944.      85424.     434.        7677.     6510.       77747.
1985     6987.      92411.     419.        8096.     6568.       84315.
1986     6987.      99399.     403.        8499.     6584.       90899.
1987     6944.     106343.     386.        8885.     6558.       97458.
1988     6922.     113265.     371.        9256.     6551.      104009.
1989     6868.     120133.     355.        9611.     6513.      110522.


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5
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              INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                 PATTERN  FOR  INDIVIDUAL  SYSTEMS

YEAR     INVESTMENT COSTS       PERIODIC EXPENSES     TOTAL EXPENDITURES
            ( MILLIONS                 OF                DOLLARS )


 1970          146.8                    2.2                   149.1
 1971          154.3                    4.5                   158.8
 1972          163.8                    7.0                   170.8
 1973          161.5                    9.4                   170.9
 1974          159.7                   11.8                   171.5
 1975          158.4                   14.2                   172.6
 1976          152.4                   16.5                   168.9
 1977          149.6                   18.7                   168.3
 1978          144.9                   20.9                   165.7
 1979          142.9                   23.0                   165.9
 1980          139.0                   25.1                   164.1
 1981          135.7                   27.1                   162.9
 1982          132.1                   29.1                   161.2
 1983          128.2                   31.0                   159.2
 1984          124.0                   32.9                   156.9
 1985          119.8                   34.7                   154.5
 1986          115.2                   36.4                   151.6
 1987          110.2                   38.1                   148.3
 1988          106.0                   39.7                   145.6
 1989          101.5                   41.2                   142.7

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
   (ADJUSTED FOR SALVAGE VALUE ) IS $        1485.2 MILLION


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
   SYSTEMS AT START OF PLANNING PERIOD )                           = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
   HOMES USING INDIVIDUAL SYSTEMS )                                = 0.25

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.
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                 INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  INDIVIDUAL  SYSTEMS

YEAR     INVESTMENT COSTS       PERIODIC EXPENSES      TOTAL EXPENDITURES
           ( MILLIONS                  OF                 DOLLARS )


 1970         146.8                       2.2                    149.1
 1971         154.3                       4.5                    158.8
 1972         163.8                       7.0                    170.8
 1973         161.5                       9.4                    170.9
 1974         159.7                      11.8                    171.5
 1975         158.4                      14.2                    172.6
 1976         152.4                      16.5                    168.9
 1977         149.6                      18.7                    168.3
 1978         144.9                      20.9                    165.7
 1979         142.9                      23.0                    165.9
 1980         139.0                      25.1                    164.1
 1981         135.7                      27.1                    162.9
 1982         132.1                      29.1                    161.2
 1983         128.2                      31.0                    159.2
 1984         124.0                      32.9                    156.9
 1985         119.8                      34.7                    154.5
 1986         115.2                      36.4                    151.6
 1987         110.2                      38.1                    148.3
 1988         106.0                      39.7                    145.6
 1989         101.5                      41.2                    142.7

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         1485.2 MILLION


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)       =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)        =   75.
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            INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                 PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:       11052        4421        2210        1105


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    40742.6     38451.6     37049.8     35890.7
   A.TREATMENT COST        :     7078.1      5330.9      4300.8      3470.6
   B.ANCILLARY COST        :     4929.3      4384.2      4019.0      3690.1
   C.OTHER COST            :    28735.2     28736.5     28730.0     28730.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
         1970                      40.5        33.1        28.6        25.0
         1971                      74.1        61.2        53.6        47.3
         1972                     109.1        90.9        80.1        71.3
         1973                     144.1       120.9       107.0        95.7
         1974                     179.7       151.5       134.7       120.9
         1975                     216.3       183.2       163.3       147.1
         1976                     252.8       214.8       192.1       173.5
         1977                     290.0       247.2       221.6       200.7
         1978                     327.4       279.9       251.4       228.2
         1979                     365.7       313.4       282.1       256.5
         1980                     404.3       347.3       313.1       285.2
         1981                     443.3       381.6       344.6       314.4
         1982                     482.6       416.3       376.5       343.9
         1983                     522.0       451.1       408.5       373.7
         1984                     561.4       485.9       440.6       403.6
         1985                     600.7       520.7       472.7       433.5
         1986                     639.6       555.3       504.7       463.2
         1987                     678.0       589.4       536.2       492.6
         1988                     716.0       623.2       567.5       521.8
         1989                     753.5       656.6       598.4       550.7

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                37655.6     35060.0     33483.1     32184.9


T1,T2,P AND M ARE                  50.0         5.0        0.15        0.25
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.    0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :           TF=0.0             AS=0.0
   FILTRATION               :           TF=0.0             AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0             AS=0.0
   LIME RECALCINATION       :           TF=0.0             AS=0.0
   AMMONIA STRIPPING        :           TF=0.0             AS=0.0
   CARBON ABSORPTION        :           TF=0.0             AS=0.0
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               INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:       11052        4421        2210        1105


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    42317.2     39691.4     38096.7     36785.8
   A.TREATMENT COST        :     8652.7      6570.7      5347.7      4365.6
   B.ANCILLARY COST        :     4929.3      4384.2      4019.0      3690.1
   C.OTHER COST            :    28735.2     28736.5     28730.0     28730.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                     87.2        62.8        49.9        40.3
          1971                    143.2       105.5        85.4        70.3
          1972                    198.0       148.1       121.3       101.2
          1973                    250.6       189.6       156.6       131.8
          1974                    302.6       231.0       192.2       162.8
          1975                    354.7       272.9       228.4       194.6
          1976                    405.9       314.3       264.3       226.3
          1977                    457.3       356.0       300.7       258.6
          1978                    508.2       397.7       337.1       291.0
          1979                    559.8       440.1       374.3       324.2
          1980                    611.3       482.6       411.7       357.7
          1981                    663.0       525.3       449.5       391.6
          1982                    714.6       568.2       487.4       425.7
          1983                    766.0       611.0       525.4       459.9
          1984                    817.1       653.6       563.3       494.1
          1985                    867.7       696.0       601.1       528.3
          1986                    917.6       737.9       638.4       562.1
          1987                    966.5       779.1       675.3       595.5
          1988                   1014.8       819.8       711.7       628.6
          1989                   1062.2       859.8       747.5       661.2

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                41054.2     37476.2     35377.6     33694.6

T1,T2,P AND M ARE                  50.0         5.0        0.15        0.25
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING          :           TF=0.166           AS=0.166
   FILTRATION              :           TF=0.166           AS=0.166
   2-STAGE LIME CLARIFICATION:         TF=0.166           AS=0.166
   LIME RECALCINATION      :           TF=0.166           AS=0.166
   AMMONIA STRIPPING       :           TF=0.166           AS=0.166
   CARBON ABSORPTION       :           TF=0.166           AS=0.166
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                  INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                      PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:       11052        4421        2210        1105


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    45488.0     42186.2     40204.8     38580.7
   A.TREATMENT COST        :    11823.5      9065.5      7455.8      6160.6
   B.ANCILLARY COST        :     4929.3      4384.2      4019.0      3690.1
   C.OTHER COST            :    28735.2     28736.5     28730.0     28730.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                    181.1       122.6        92.6        70.9
          1971                    282.5       194.7       149.4       116.4
          1972                    377.0       263.2       204.2       161.1
          1973                    465.0       327.9       256.5       204.2
          1974                    549.9       391.0       307.9       246.9
          1975                    633.5       453.6       359.3       289.9
          1976                    714.2       514.4       409.6       332.2
          1977                    794.0       575.0       459.9       374.8
          1978                    872.3       634.8       509.7       417.2
          1979                    950.7       695.0       560.1       460.2
          1980                   1028.3       754.8       610.3       503.2
          1981                   1105.4       814.4       660.6       546.4
          1982                   1181.8       873.8       710.8       589.6
          1983                   1257.3       932.8       760.8       632.8
          1984                   1331.8       991.1       810.3       675.7
          1985                   1405.2      1048.7       859.4       718.3
          1986                   1477.2      1105.4       907.8       760.4
          1987                   1547.5      1160.9       955.3       801.8
          1988                   1616.4      1215.4      1002.0       842.6
          1989                   1683.7      1268.9      1047.9       882.7

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                47897.6     42338.2     39192.5     36722.3

T1,T2,P AND M ARE                  50.0         5.0        0.15        0.25
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.     25.     50.  0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.500            AS=0.500
   FILTRATION                :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500            AS=0.500
   LIME RECALCINATION        :          TF=0.500            AS=0.500
   AMMONIA STRIPPING         :          TF=0.500            AS=0.500
   CARBON ABSORPTION         :          TF=0.500            AS=0.500
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               INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                    PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:      11052       4421       2210       1105


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    50231.6    45919.1    43354.1    41265.8
   A.TREATMENT COST        :    16567.2    12798.4    10605.1     8845.7
   B.ANCILLARY COST        :     4929.3     4384.2     4019.0     3690.1
   C.OTHER COST            :    28735.2    28736.5    28730.0    28730.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                    321.6      212.1      156.4      116.7
          1971                    490.8      328.1      245.0      185.4
          1972                    644.8      435.5      328.1      250.8
          1973                    785.8      534.8      405.7      312.5
          1974                    920.0      630.3      480.9      372.7
          1975                   1050.6      723.8      555.0      432.5
          1976                   1175.3      813.8      626.6      490.6
          1977                   1297.8      902.6      697.7      548.6
          1978                   1417.0      989.5      767.5      605.8
          1979                   1535.6     1076.3      837.6      663.5
          1980                   1652.1     1162.0      907.0      720.8
          1981                   1767.2     1247.0      976.0      777.9
          1982                   1880.7     1331.1     1044.5      834.9
          1983                   1992.3     1414.2     1112.4      891.4
          1984                   2101.9     1496.0     1179.3      947.4
          1985                   2209.5     1576.4     1245.4     1002.7
          1986                   2314.5     1655.2     1310.2     1057.1
          1987                   2416.6     1732.1     1373.6     1110.4
          1988                   2516.4     1807.4     1435.8     1162.8
          1989                   2613.6     1880.8     1496.6     1214.2

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                58135.8    49613.1    44891.5    41251.5

T1,T2,P AND M ARE                  50.0        5.0       0.15       0.25
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.     25.     50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=1.000             AS=1.000
   FILTRATION                 :          TF=1.000             AS=1.000
   2-STAGE LIME CLARIFICATION:           TF=1.000             AS=1.000
   LIME RECALCINATION         :          TF=1.000             AS=1.000
   AMMONIA STRIPPING          :          TF=1.000             AS=1.000
   CARBON ABSORPTION          :          TF=1.000             AS=1.000
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B. Case 1. $t_1 = t_2 = 5$ years; $M = .33$

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                      PROJECTED  DEMAND  FOR
                    INDIVIDUAL  AND  CENTRAL
                       SEWAGE  SYSTEMS

          POPULATION  IN        THOSE  SERVED  BY      THOSE  SERVED  BY
        INDIVIDUAL  HOMES      INDIVIDUAL  SYSTEMS     CENTRAL  SYSTEMS
          (THOUSANDS)              (THOUSANDS)             (THOUSANDS)
 YEAR  INCREMENT  CUMULATIVE INCREMENT  CUMULATIVE INCREMENT  CUMULATIVE
 1970     3426.       3426.     514.        514.     2913.       2913.
 1971     3959.       7386.     540.       1054.     3419.       6332.
 1972     4586.      11972.     573.       1627.     4013.      10345.
 1973     4900.      16872.     565.       2193.     4335.      14680.
 1974     5217.      22089.     559.       2752.     4658.      19338.
 1975     5544.      27633.     712.       3463.     4832.      24170.
 1976     5691.      33324.     859.       4323.     4832.      29001.
 1977     5935.      39259.    1034.       5357.     4902.      33903.
 1978     6085.      45344.    1199.       6555.     4886.      38789.
 1979     6336.      51681.    1385.       7940.     4951.      43741.
 1980     6488.      58169.    1546.       9486.     4942.      48683.
 1981     6651.      64820.    1701.      11187.     4950.      53633.
 1982     6781.      71601.    1835.      13022.     4946.      58579.
 1983     6879.      78480.    1948.      14970.     4931.      63510.
 1984     6944.      85424.    2037.      17007.     4907.      68417.
 1985     6987.      92411.    2107.      19114.     4880.      73297.
 1986     6987.      99399.    2153.      21267.     4835.      78132.
 1987     6944.     106343.    2175.      23441.     4769.      82902.
 1988     6922.     113265.    2195.      25637.     4727.      87629.
 1989     6868.     120133.    2199.      27836.     4669.      92297.


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                      =  3.5
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                   INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                      PATTERN  FOR  INDIVIDUAL  SYSTEMS

YEAR     INVESTMENT COSTS        PERIODIC EXPENSES      TOTAL EXPENDITURES
            ( MILLIONS                   OF                 DOLLARS )


 1970          146.8                        2.2                    149.1
 1971          154.3                        4.5                    158.8
 1972          163.8                        7.0                    170.8
 1973          161.5                        9.4                    170.9
 1974          159.7                       11.8                    171.5
 1975          254.2                       17.9                    272.1
 1976          306.9                       25.3                    332.2
 1977          369.2                       34.1                    403.3
 1978          428.0                       44.4                    472.4
 1979          494.6                       56.3                    550.9
 1980          552.2                       69.5                    621.7
 1981          607.4                       84.1                    691.5
 1982          655.5                       99.8                    755.3
 1983          695.6                      116.5                    812.1
 1984          727.5                      134.0                    861.5
 1985          752.5                      152.0                    904.6
 1986          768.8                      170.5                    939.3
 1987          776.7                      189.1                    965.8
 1988          784.0                      207.9                    992.0
 1989          785.4                      226.8                   1012.2

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3497.1 MILLION


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.
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               INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                  PATTERN  FOR  INDIVIDUAL  SYSTEMS

YEAR    INVESTMENT COSTS       PERIODIC EXPENSES      TOTAL EXPENDITURES
          ( MILLIONS                  OF                 DOLLARS )


 1970        146.8                       2.2                   149.1
 1971        154.3                       4.5                   158.8
 1972        163.8                       7.0                   170.8
 1973        161.5                       9.4                   170.9
 1974        159.7                      11.8                   171.5
 1975        254.2                      27.0                   281.3
 1976        306.9                      45.5                   352.4
 1977        369.2                      67.6                   436.8
 1978        428.0                      93.3                   521.3
 1979        494.6                     123.0                   617.6
 1980        552.2                     156.1                   708.3
 1981        607.4                     192.6                   800.0
 1982        655.5                     231.9                   887.4
 1983        695.6                     273.6                   969.2
 1984        727.5                     317.3                  1044.8
 1985        752.5                     362.4                  1115.0
 1986        768.8                     408.5                  1177.3
 1987        776.7                     455.1                  1231.8
 1988        784.0                     502.2                  1286.2
 1989        785.4                     549.3                  1334.7

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         4373.8 MILLION


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.
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                 INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    34025.9    32111.2    30947.4    29979.2
   A.TREATMENT COST        :     5911.2     4451.8     3592.4     2899.0
   B.ANCILLARY COST        :     4116.6     3661.3     3357.0     3082.2
   C.OTHER COST            :    23998.0    23998.0    23998.0    23998.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                     38.9       31.8       27.6       24.2
          1971                     71.3       59.1       51.8       45.9
          1972                    105.1       87.9       77.6       69.3
          1973                    139.0      117.0      103.9       93.1
          1974                    173.6      146.8      130.9      117.8
          1975                    208.0      176.7      158.0      142.7
          1976                    241.2      205.6      184.3      166.9
          1977                    274.1      234.3      210.6      191.1
          1978                    306.1      262.4      236.2      214.8
          1979                    338.0      290.3      261.8      238.5
          1980                    369.2      317.8      287.1      261.8
          1981                    400.0      345.0      312.0      285.0
          1982                    430.4      371.8      336.7      307.9
          1983                    460.3      398.3      361.1      330.6
          1984                    489.8      424.3      385.2      353.0
          1985                    518.8      450.1      408.9      375.1
          1986                    547.2      475.3      432.2      396.9
          1987                    575.1      500.1      455.1      418.3
          1988                    602.4      524.4      477.7      439.3
          1989                    629.3      548.3      499.8      460.0

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                31681.9    29483.0    28154.5    27055.2

T1,T2,P AND M ARE                   5.0        5.0       0.15       0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.  0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.0              AS=0.0
   FILTRATION                :          TF=0.0              AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0              AS=0.0
   LIME RECALCINATION        :          TF=0.0              AS=0.0
   AMMONIA STRIPPING         :          TF=0.0              AS=0.0
   CARBON ABSORPTION         :          TF=0.0              AS=0.0
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                 INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :     10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:         9230        3692        1846         923


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :     35342.1     33146.6     31820.3     30728.3
   A.TREATMENT COST        :      7227.4      5487.3      4465.4      3648.1
   B.ANCILLARY COST        :      4116.6      3661.3      3357.0      3082.2
   C.OTHER COST            :     23998.0     23998.0     23998.0     23998.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                      81.6        59.0        47.1        38.2
          1971                     134.6        99.7        81.0        67.1
          1972                     186.6       140.4       115.4        96.8
          1973                     236.7       180.1       149.4       126.4
          1974                     286.4       219.9       183.7       156.5
          1975                     334.7       258.9       217.5       186.4
          1976                     380.7       296.3       250.1       215.3
          1977                     425.5       332.9       282.1       243.8
          1978                     468.7       368.3       313.3       271.6
          1979                     511.2       403.4       344.1       299.2
          1980                     552.5       437.6       374.3       326.3
          1981                     593.0       471.2       404.1       353.1
          1982                     632.7       504.2       433.3       379.5
          1983                     671.5       536.6       462.1       405.5
          1984                     709.5       568.4       490.4       431.1
          1985                     746.8       599.7       518.3       456.3
          1986                     783.2       630.3       545.6       481.0
          1987                     818.6       660.1       572.3       505.3
          1988                     853.3       689.4       598.5       529.1
          1989                     887.3       718.1       624.2       552.5

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 34611.3     31559.5     29777.2     28351.0

T1,T2,P AND M ARE                    5.0         5.0        0.15        0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.   25.   50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :         TF=0.166            AS=0.166
   FILTRATION                 :         TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:          TF=0.166            AS=0.166
   LIME RECALCINATION         :         TF=0.166            AS=0.166
   AMMONIA STRIPPING          :         TF=0.166            AS=0.166
   CARBON ABSORPTION          :         TF=0.166            AS=0.166
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                 INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:        9230        3692        1846         923

TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    37988.2     35229.2     33583.3     32276.5
   A.TREATMENT COST        :     9873.6      7569.9      6228.3      5146.3
   B.ANCILLARY COST        :     4116.6      3661.3      3357.0      3082.2
   C.OTHER COST            :    23998.0     23998.0     23998.0     23998.0

PERIODIC EXPENSES BY YEAR ($ MILLIONS)
         1970                     167.4       113.8        86.3        66.3
         1971                     262.0       181.5       139.8       109.5
         1972                     350.6       246.0       191.7       151.9
         1973                     433.2       307.1       241.4       193.1
         1974                     513.1       366.8       290.3       233.9
         1975                     589.5       424.3       337.8       273.9
         1976                     661.0       478.6       382.9       312.0
         1977                     729.8       531.1       426.7       349.3
         1978                     795.4       581.5       468.9       385.2
         1979                     859.4       630.8       510.3       420.7
         1980                     921.1       678.5       550.6       455.3
         1981                     981.0       725.1       589.9       489.2
         1982                    1039.3       770.6       628.5       522.5
         1983                    1096.1       815.0       666.2       555.2
         1984                    1151.3       858.3       703.1       587.2
         1985                    1205.1       900.6       739.2       618.6
         1986                    1257.5       941.9       774.5       649.3
         1987                    1308.3       982.0       808.9       679.3
         1988                    1357.8      1021.3       842.5       708.6
         1989                    1406.0      1059.5       875.4       737.4

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                40500.6     35736.2     33054.5     30942.5

T1,T2,P AND M ARE                   5.0         5.0        0.15        0.33
HORIZ. TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.   0.06

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :            TF=0.500              AS=0.500
   FILTRATION                 :            TF=0.500              AS=0.500
   2-STAGE LIME CLARIFICATION:             TF=0.500              AS=0.500
   LIME RECALCINATION         :            TF=0.500              AS=0.500
   AMMONIA STRIPPING          :            TF=0.500              AS=0.500
   CARBON ABSORPTION          :            TF=0.500              AS=0.500
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                    INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                        PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION           :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )     :    41950.6    38347.3    36213.4    34468.9
   A.TREATMENT COST         :    13836.0    10688.0     8858.4     7388.7
   B.ANCILLARY COST         :     4116.6     3661.3     3357.0     3082.2
   C.OTHER COST             :    23998.0    23998.0    23998.0    23998.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                     296.0      195.8      144.8      108.3
          1971                     452.8      303.8      227.7      172.9
          1972                     596.0      404.1      305.6      234.5
          1973                     727.4      497.1      378.6      292.8
          1974                     852.6      586.7      449.4      349.8
          1975                     971.0      671.9      517.3      404.8
          1976                    1080.8      751.5      581.0      456.8
          1977                    1185.5      827.9      642.4      507.1
          1978                    1284.7      900.5      701.0      555.3
          1979                    1380.8      971.2      758.2      602.6
          1980                    1472.9     1039.2      813.5      648.2
          1981                    1562.0     1105.3      867.3      693.0
          1982                    1648.3     1169.4      919.6      736.7
          1983                    1731.8     1231.7      970.6      779.3
          1984                    1812.8     1292.2     1020.3      820.8
          1985                    1891.5     1351.2     1068.8      861.5
          1986                    1967.8     1408.5     1116.0      901.2
          1987                    2041.5     1464.0     1161.8      939.7
          1988                    2113.2     1518.1     1206.5      977.4
          1989                    2182.8     1570.7     1250.1     1014.2

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 49319.4    41989.3    37943.8    34821.4

T1,T2,P AND M ARE                    5.0        5.0       0.15       0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=1.000            AS=1.000
   FILTRATION               :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:         TF=1.000            AS=1.000
   LIME RECALCINATION       :          TF=1.000            AS=1.000
   AMMONIA STRIPPING        :          TF=1.000            AS=1.000
   CARBON ABSORPTION        :          TF=1.000            AS=1.000
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C. Case 2. t_1 = 5 years; t_2 = 10 years; M = .33

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                    PROJECTED  DEMAND  FOR
                 INDIVIDUAL  AND  CENTRAL
                      SEWAGE  SYSTEMS

        POPULATION  IN       THOSE  SERVED  BY     THOSE  SERVED  BY
      INDIVIDUAL  HOMES    INDIVIDUAL  SYSTEMS    CENTRAL  SYSTEMS
         (THOUSANDS)             (THOUSANDS)            (THOUSANDS)
YEAR  INCREMENT  CUMULATIVE INCREMENT  CUMULATIVE INCREMENT  CUMULATIVE
1970     3426.       3426.     514.         514.     2913.       2913.
1971     3959.       7386.     540.        1054.     3419.       6332.
1972     4586.      11972.     573.        1627.     4013.      10345.
1973     4900.      16872.     565.        2193.     4335.      14680.
1974     5217.      22089.     559.        2752.     4658.      19338.
1975     5544.      27633.     652.        3403.     4892.      24230.
1976     5691.      33324.     731.        4134.     4960.      29190.
1977     5935.      39259.     828.        4962.     5107.      34297.
1978     6085.      45344.     919.        5881.     5166.      39463.
1979     6336.      51681.    1030.        6912.     5306.      44769.
1980     6488.      58169.    1130.        8042.     5358.      50127.
1981     6651.      64820.    1235.        9277.     5416.      55543.
1982     6781.      71601.    1336.       10612.     5446.      60989.
1983     6879.      78480.    1431.       12043.     5448.      66437.
1984     6944.      85424.    1518.       13561.     5426.      71863.
1985     6987.      92411.    1598.       15159.     5389.      77253.
1986     6987.      99399.    1665.       16824.     5322.      82575.
1987     6944.     106343.    1717.       18541.     5227.      87802.
1988     6922.     113265.    1770.       20311.     5152.      92954.
1989     6868.     120133.    1810.       22121.     5058.      98012.


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5
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                  INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                      PATTERN  FOR  INDIVIDUAL  SYSTEMS

YEAR     INVESTMENT COSTS        PERIODIC EXPENSES      TOTAL EXPENDITURES
           ( MILLIONS                   OF                  DOLLARS )


 1970          146.8                        2.2                      149.1
 1971          154.3                        4.5                      158.8
 1972          163.8                        7.0                      170.8
 1973          161.5                        9.4                      170.9
 1974          159.7                       11.8                      171.5
 1975          232.8                       17.4                      250.1
 1976          261.0                       23.6                      284.6
 1977          295.9                       30.7                      326.6
 1978          328.2                       38.6                      366.8
 1979          367.9                       47.4                      415.4
 1980          403.6                       57.1                      460.7
 1981          441.0                       67.7                      508.8
 1982          477.0                       79.2                      556.2
 1983          510.9                       91.4                      602.4
 1984          542.1                      104.4                      646.5
 1985          570.7                      118.1                      688.9
 1986          594.7                      132.4                      727.1
 1987          613.3                      147.1                      760.5
 1988          632.2                      162.3                      794.5
 1989          646.3                      177.8                      824.1

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         2872.8 MILLION


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.
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                    INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                        PATTERN  FOR  INDIVIDUAL  SYSTEMS

YEAR    INVESTMENT COSTS        PERIODIC EXPENSES     TOTAL EXPENDITURES
           ( MILLIONS                  OF                  DOLLARS )


 1970          146.8                      2.2                  149.1
 1971          154.3                      4.5                  158.8
 1972          163.8                      7.0                  170.8
 1973          161.5                      9.4                  170.9
 1974          159.7                     11.8                  171.5
 1975          232.8                     25.8                  258.5
 1976          261.0                     41.4                  302.4
 1977          295.9                     59.2                  355.1
 1978          328.2                     78.9                  407.0
 1979          367.9                    100.9                  468.9
 1980          403.6                    125.2                  528.8
 1981          441.0                    151.6                  592.7
 1982          477.0                    180.2                  657.3
 1983          510.9                    210.9                  721.8
 1984          542.1                    243.4                  785.5
 1985          570.7                    277.7                  848.4
 1986          594.7                    313.3                  908.0
 1987          613.3                    350.1                  963.5
 1988          632.2                    388.1                 1020.3
 1989          646.3                    426.8                 1073.2

THE TOTAL PRESENT VALUE CF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3551.2 MILLION


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33

H  (PLANNING HORIZON, YEARS)                                    =    20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =    25.
HS (LIFETIME OF SEWER, YEARS)                                   =    50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =    20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =    15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =    75.
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                INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                    PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :    10000.0     25000.0     50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9801        3920        1960        980


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :    36130.8     34094.1     32858.4    31831.4
   A.TREATMENT COST        :     6276.9      4726.8      3814.3     3078.0
   B.ANCILLARY COST        :     4371.3      3887.3      3564.1     3273.5
   C.OTHER COST            :    25482.6     25480.0     25480.0    25480.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                     39.4        32.2        28.0       24.5
          1971                     72.2        59.8        52.4       46.4
          1972                    106.4        88.9        78.4       69.9
          1973                    140.7       118.3       104.9       94.0
          1974                    175.6       148.4       132.1      118.8
          1975                    210.7       178.8       159.7      144.2
          1976                    245.2       208.8       187.0      169.2
          1977                    279.7       238.9       214.5      194.5
          1978                    313.8       268.7       241.8      219.7
          1979                    348.2       298.8       269.3      245.2
          1980                    382.2       328.7       296.8      270.6
          1981                    416.0       358.6       324.2      296.1
          1982                    449.6       388.2       351.5      321.4
          1983                    482.7       417.5       378.4      346.5
          1984                    515.4       446.4       405.1      371.3
          1985                    547.4       474.8       431.3      395.7
          1986                    578.8       502.6       457.0      419.7
          1987                    609.3       529.7       482.1      443.1
          1988                    639.1       556.3       506.7      466.0
          1989                    668.2       582.2       530.7      488.5

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                33565.8     31237.4     29832.6    28671.4

T1,T2,P AND M ARE                   5.0        10.0        0.15       0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :         TF=0.0               AS=0.0
   FILTRATION                 :         TF=0.0               AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0               AS=0.0
   LIME RECALCINATION         :         TF=0.0               AS=0.0
   AMMONIA STRIPPING          :         TF=0.0               AS=0.0
   CARBON ABSORPTION          :         TF=0.0               AS=0.0
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              INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                  PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION           :     10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:          9801        3920        1960         980


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )     :     37527.7     35193.7     33785.5     32624.3
   A.TREATMENT COST         :      7673.8      5826.4      4741.4      3870.8
   B.ANCILLARY COST         :      4371.3      3887.3      3564.1      3273.5
   C.OTHER COST             :     25482.6     25480.0     25480.0     25480.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
         1970                        83.4        60.3        48.0        38.9
         1971                       137.4       101.6        82.4        68.1
         1972                       190.3       142.9       117.3        98.2
         1973                       241.2       183.2       151.7       128.1
         1974                       291.6       223.5       186.4       158.5
         1975                       341.2       263.5       221.1       189.0
         1976                       389.1       302.3       254.9       218.9
         1977                       436.3       340.9       288.5       248.9
         1978                       482.5       378.7       321.7       278.4
         1979                       528.4       416.5       355.0       308.2
         1980                       573.6       453.9       387.9       337.7
         1981                       618.2       490.8       420.6       367.1
         1982                       662.0       527.3       453.0       396.2
         1983                       705.1       563.2       484.9       425.0
         1984                       747.2       598.5       516.2       453.4
         1985                       788.4       633.0       547.0       481.2
         1986                       828.5       666.7       577.1       508.5
         1987                       867.4       699.5       606.3       535.0
         1988                       905.3       731.4       634.9       561.0
         1989                       942.0       762.4       662.8       586.3

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                  36645.7     33423.3     31541.9     30032.3

T1,T2,P AND M ARE                     5.0        10.0        0.15        0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :         TF=0.166             AS=0.166
   FILTRATION                :         TF=0.166             AS=0.166
   2-STAGE LIME CLARIFICATION:         TF=0.166             AS=0.166
   LIME RECALCINATION        :         TF=0.166             AS=0.166
   AMMONIA STRIPPING         :         TF=0.166             AS=0.166
   CARBON ABSORPTION         :         TF=0.166             AS=0.166
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                 INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION           :     10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:          9801        3920        1960         980


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )     :     40338.7     37404.7     35656.9     34219.8
   A.TREATMENT COST         :     10484.8      8037.4      6612.8      5466.3
   B.ANCILLARY COST         :      4371.3      3887.3      3564.1      3273.5
   C.OTHER COST             :     25482.6     25480.0     25480.0     25480.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
         1970                       171.9       116.6        88.3        67.8
         1971                       268.6       185.7       142.9       111.8
         1972                       359.1       251.5       195.8       155.0
         1973                       443.5       313.8       246.3       196.8
         1974                       525.0       374.5       296.0       238.3
         1975                       603.8       433.8       344.8       279.3
         1976                       678.6       490.4       391.8       318.9
         1977                       751.5       545.9       438.0       358.2
         1978                       821.8       599.8       483.0       396.6
         1979                       891.2       653.2       527.9       435.0
         1980                       958.7       705.4       571.9       472.7
         1981                      1024.9       756.7       615.2       510.1
         1982                      1089.5       807.1       657.9       546.9
         1983                      1152.5       856.3       699.7       583.1
         1984                      1213.8       904.4       740.6       618.6
         1985                      1273.4       951.2       780.6       653.3
         1986                      1331.1       996.7       819.4       687.2
         1987                      1386.8      1040.7       857.1       720.1
         1988                      1440.8      1083.5       893.8       752.1
         1989                      1493.1      1124.9       929.4       783.3

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                  42843.3     37818.7     34992.1     32770.9

T1,T2,P AND M ARE                     5.0        10.0        0.15        0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.    25.    50.   0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.500            AS=0.500
   FILTRATION                :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500            AS=0.500
   LIME RECALCINATION        :          TF=0.500            AS=0.500
   AMMONIA STRIPPING         :          TF=0.500            AS=0.500
   CARBON ABSORPTION         :          TF=0.500            AS=0.500
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                 INVESTMENT  COSTS  AND  PERIODIC  EXPENSES
                     PATTERN  FOR  CENTRAL  SYSTEMS

DESIGN POPULATION          :   10000.0     25000.0     50000.0    100000.0

NUMBER OF SYSTEMS REQUIRED:       9801        3920        1960         980


TOTAL INVESTMENT COSTS
  (=A+B+C, $ MILLIONS )    :   44545.8     40715.3     38449.6     36598.4
   A.TREATMENT COST        :   14691.9     11348.1      9405.5      7845.0
   B.ANCILLARY COST        :    4371.3      3887.3      3564.1      3273.5
   C.OTHER COST            :   25482.6     25480.0     25480.0     25480.0


PERIODIC EXPENSES BY YEAR ($ MILLIONS)
          1970                   304.3       201.0       148.6       111.0
          1971                   465.1       311.6       233.3       176.9
          1972                   611.8       414.2       312.9       239.7
          1973                   746.3       509.3       387.4       299.1
          1974                   874.4       600.7       459.6       357.2
          1975                   996.9       688.8       529.6       413.9
          1976                  1111.9       772.0       596.1       468.0
          1977                  1223.1       852.9       661.0       521.2
          1978                  1329.7       930.8       723.8       572.8
          1979                  1434.1      1007.5       785.8       623.9
          1980                  1535.1      1082.0       846.3       674.0
          1981                  1633.6      1154.9       905.7       723.2
          1982                  1729.2      1226.0       963.7       771.5
          1983                  1822.1      1295.2      1020.3       818.8
          1984                  1912.1      1362.4      1075.4       864.9
          1985                  1999.2      1427.7      1129.1       909.9
          1986                  2083.3      1490.8      1181.1       953.6
          1987                  2164.2      1551.7      1231.3       995.9
          1988                  2242.4      1610.7      1280.1      1037.0
          1989                  2317.8      1667.7      1327.3      1076.9

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                               52118.8     44399.9     40141.0     36853.8

T1,T2,P AND M ARE                  5.0        10.0        0.15        0.33
HORIZ.,TREAT. PLANT LIFE,SEWER LIFE,DISC. RATE=   20.     25.     50.  0.06


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=1.000            AS=1.000
   FILTRATION                 :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:           TF=1.000            AS=1.000
   LIME RECALCINATION         :          TF=1.000            AS=1.000
   AMMONIA STRIPPING          :          TF=1.000            AS=1.000
   CARBON ABSORPTION          :          TF=1.000            AS=1.000
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II SUMMARY PRINTOUTS OF SYSTEM COSTS

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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                 (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
   (ADJUSTED FOR SALVAGE VALUE ) IS $          1485.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       11052       4421       2210       1105

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                37655.6    35060.0    33483.1    32184.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              39140.9    36545.3    34968.4    33670.1

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :            TF=0.0              AS=0.0
   FILTRATION                :            TF=0.0              AS=0.0
   2-STAGE LIME CLARIFICATION:            TF=0.0              AS=0.0
   LIME RECALCINATION        :            TF=0.0              AS=0.0
   AMMONIA STRIPPING         :            TF=0.0              AS=0.0
   CARBON ABSORPTION         :            TF=0.0              AS=0.0
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          1485.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       11052       4421       2210       1105

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                41054.2    37476.2    35377.6    33694.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              42539.4    38961.5    36862.9    35179.9

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                             = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.166            AS=0.166
   FILTRATION                 :          TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:           TF=0.166            AS=0.166
   LIME RECALCINATION         :          TF=0.166            AS=0.166
   AMMONIA STRIPPING          :          TF=0.166            AS=0.166
   CARBON ABSORPTION          :          TF=0.166            AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         1485.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       11052       4421       2210       1105

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                47897.6    42339.2    39192.5    36722.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             49382.8    43823.5    40677.7    38207.5

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )
                                                                 = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )
                                                                 = 0.25

PH(PEOPLE PER INDIVIDUAL HOME)
                                                                 =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.500            AS=0.500
   FILTRATION                 :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:           TF=0.500            AS=0.500
   LIME RECALCINATION         :          TF=0.500            AS=0.500
   AMMONIA STRIPPING          :          TF=0.500            AS=0.500
   CARBON ABSORPTION          :          TF=0.500            AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          1485.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       11052       4421       2210       1105

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                58135.8    49613.1    44891.5    41251.5

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             59621.1    51098.4    46376.7    42736.8

       VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=  50.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING          :          TF=1.000          AS=1.000
   FILTRATION              :          TF=1.000          AS=1.000
   2-STAGE LIME CLARIFICATION:        TF=1.000          AS=1.000
   LIME RECALCINATION      :          TF=1.000          AS=1.000
   AMMONIA STRIPPING       :          TF=1.000          AS=1.000
   CARBON ABSORPTION       :          TF=1.000          AS=1.000
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
            (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         2990.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                33444.7    31126.7    29734.7    28577.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              36435.5    34117.6    32725.5    31568.3

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=0.0            AS=0.0
   FILTRATION               :          TF=0.0            AS=0.0
   2-STAGE LIME CLARIFICATION:         TF=0.0            AS=0.0
   LIME RECALCINATION       :          TF=0.0            AS=0.0
   AMMONIA STRIPPING        :          TF=0.0            AS=0.0
   CARBON ABSORPTION        :          TF=0.0            AS=0.0
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
   [illegible]DJUSTED FOR SALVAGE VALUE ) IS $          2990.8 MILLION
FOR [illegible]NTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                36511.1    33304.5    31437.6    29929.2

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             39501.9    36295.3    34428.4    32920.1

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING              :         TF=0.166            AS=0.166
   FILTRATION                  :         TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:           TF=0.166            AS=0.166
   LIME RECALCINATION          :         TF=0.166            AS=0.166
   AMMONIA STRIPPING           :         TF=0.166            AS=0.166
   CARBON ABSORPTION           :         TF=0.166            AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         2990.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                42685.4    37683.5    34875.1    32657.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               45676.2    40674.3    37865.9    35648.7

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :         TF=0.500            AS=0.500
   FILTRATION                :         TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:         TF=0.500            AS=0.500
   LIME RECALCINATION        :         TF=0.500            AS=0.500
   AMMONIA STRIPPING         :         TF=0.500            AS=0.500
   CARBON ABSORPTION         :         TF=0.500            AS=0.500
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
             (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         2990.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                51922.3    44236.9    40005.0    36729.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              54913.2    47227.7    42995.8    39720.7

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1( ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2( ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=1.000          AS=1.000
   FILTRATION                :          TF=1.000          AS=1.000
   2-STAGE LIME CLARIFICATION:          TF=1.000          AS=1.000
   LIME RECALCINATION        :          TF=1.000          AS=1.000
   AMMONIA STRIPPING         :          TF=1.000          AS=1.000
   CARBON ABSORPTION         :          TF=1.000          AS=1.000
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                  SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3497.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                31681.9    29483.0    28154.5    27055.2

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              35178.9    32980.1    31651.6    30552.3

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.0              AS=0.0
   FILTRATION                :          TF=0.0              AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0              AS=0.0
   LIME RECALCINATION        :          TF=0.0              AS=0.0
   AMMONIA STRIPPING         :          TF=0.0              AS=0.0
   CARBON ABSORPTION         :          TF=0.0              AS=0.0
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                  SUMMARY  OF  SEWAGE  SYSTEM  COSTS
            (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3497.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                34611.3    31559.5    29777.2    28351.0

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              38108.4    35056.6    33274.3    31848.1

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.166          AS=0.166
   FILTRATION                :          TF=0.166          AS=0.166
   2-STAGE LIME CLARIFICATION:          TF=0.166          AS=0.166
   LIME RECALCINATION        :          TF=0.166          AS=0.166
   AMMONIA STRIPPING         :          TF=0.166          AS=0.166
   CARBON ABSORPTION         :          TF=0.166          AS=0.166
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
             (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3497.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION         :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                40500.6    35736.2    33054.5    30942.5

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              43997.7    39233.3    36551.6    34439.6

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :         TF=0.500            AS=0.500
   FILTRATION                :         TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:         TF=0.500            AS=0.500
   LIME RECALCINATION        :         TF=0.500            AS=0.500
   AMMONIA STRIPPING         :         TF=0.500            AS=0.500
   CARBON ABSORPTION         :         TF=0.500            AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3497.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :     10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:         9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 49319.4    41989.3    37943.8    34821.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)                52816.5    45486.4    41440.9    38318.5

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=1.000            AS=1.000
   FILTRATION                 :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:           TF=1.000            AS=1.000
   LIME RECALCINATION         :          TF=1.000            AS=1.000
   AMMONIA STRIPPING          :          TF=1.000            AS=1.000
   CARBON ABSORPTION          :          TF=1.000            AS=1.000
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
             (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3942.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION         :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                               30115.7    28023.0    26750.0    25703.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             34058.4    31965.7    30692.7    29646.0

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                             = 0.40

PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING              :          TF=0.0              AS=0.0
   FILTRATION                  :          TF=0.0              AS=0.0
   2-STAGE LIME CLARIFICATION:            TF=0.0              AS=0.0
   LIME RECALCINATION          :          TF=0.0              AS=0.0
   AMMONIA STRIPPING           :          TF=0.0              AS=0.0
   CARBON ABSORPTION           :          TF=0.0              AS=0.0
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                   SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITUPE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3942.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITUPE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                32917.7    30009.2    28306.6    26933.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              36860.4    33951.9    32249.3    30876.0

          VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )
                                                                 = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )
                                                                 = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)
                                                                 =  3.5

H  (PLANNING HORIZON, YEARS)
                                                                 =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE CCST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.166           AS=0.166
   FILTRATION                 :          TF=0.166           AS=0.166
   2-STAGE LIME CLARIFICATION:           TF=0.166           AS=0.166
   LIME RECALCINATION         :          TF=0.166           AS=0.166
   AMMONIA STRIPPING          :          TF=0.166           AS=0.166
   CARBON ABSORPTION          :          TF=0.166           AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3942.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :     10000.0     25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:         8752        3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 38560.3     34008.9    31435.8    29418.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               42503.0     37951.7    35378.5    33361.3

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=0.500            AS=0.500
   FILTRATION               :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:         TF=0.500            AS=0.500
   LIME RECALCINATION       :          TF=0.500            AS=0.500
   AMMONIA STRIPPING        :          TF=0.500            AS=0.500
   CARBON ABSORPTION        :          TF=0.500            AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3942.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                47004.8    39991.5    36110.8    33125.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              50947.6    43934.2    40053.5    37068.1

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   20.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :           TF=1.000          AS=1.000
   FILTRATION                 :           TF=1.000          AS=1.000
   2-STAGE LIME CLARIFICATION:            TF=1.000          AS=1.000
   LIME RECALCINATION         :           TF=1.000          AS=1.000
   AMMONIA STRIPPING          :           TF=1.000          AS=1.000
   CARBON ABSORPTION          :           TF=1.000          AS=1.000
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                 (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          2609.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                34596.1    32204.1    30750.0    29568.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              37205.1    34813.1    33359.0    32177.9

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   30.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :        TF=0.0            AS=0.0
   FILTRATION                :        TF=0.0            AS=0.0
   2-STAGE LIME CLARIFICATION:        TF=0.0            AS=0.0
   LIME RECALCINATION        :        TF=0.0            AS=0.0
   AMMONIA STRIPPING         :        TF=0.0            AS=0.0
   CARBON ABSORPTION         :        TF=0.0            AS=0.0
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                   SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         2609.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                37755.3    34447.8    32507.8    30964.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             40364.3    37056.8    35116.8    33573.6

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.166          AS=0.166
   FILTRATION                 :          TF=0.166          AS=0.166
   2-STAGE LIME CLARIFICATION:           TF=0.166          AS=0.166
   LIME RECALCINATION         :          TF=0.166          AS=0.166
   AMMONIA STRIPPING          :          TF=0.166          AS=0.166
   CARBON ABSORPTION          :          TF=0.166          AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          2609.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION           :     10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                  44115.0    38962.0    36044.4    33772.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)                46724.0    41571.0    38653.3    36381.8

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                      =  3.5

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)       =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)        =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :           TF=0.500            AS=0.500
   FILTRATION               :           TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500            AS=0.500
   LIME RECALCINATION       :           TF=0.500            AS=0.500
   AMMONIA STRIPPING        :           TF=0.500            AS=0.500
   CARBON ABSORPTION        :           TF=0.500            AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          2609.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                53632.0    45716.7    41333.5    37976.7

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              56241.0    48325.7    43942.4    40585.6

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=1.000            AS=1.000
   FILTRATION                :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:          TF=1.000            AS=1.000
   LIME RECALCINATION        :          TF=1.000            AS=1.000
   AMMONIA STRIPPING         :          TF=1.000            AS=1.000
   CARBON ABSORPTION         :          TF=1.000            AS=1.000
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          2872.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                33565.8    31237.4    29832.6    28671.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              36438.6    34110.3    32705.5    31544.2

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.0               AS=0.0
   FILTRATION                :          TF=0.0               AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0               AS=0.0
   LIME RECALCINATION        :          TF=0.0               AS=0.0
   AMMONIA STRIPPING         :          TF=0.0               AS=0.0
   CARBON ABSORPTION         :          TF=0.0               AS=0.0
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          2872.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                36645.7    33423.3    31541.9    30032.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             39518.5    36296.2    34414.8    32905.2

          VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33

PH(PEOPLE PER INDIVIDUAL HOME)                                      =  3.5

H  (PLANNING HORIZON, YEARS)                                        =  20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)              =  25.
HS (LIFETIME OF SEWER, YEARS)                                       =  50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                           =  20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                      = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                   = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                 = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                  = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)        =  15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)         =  30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING          :          TF=0.166            AS=0.166
   FILTRATION              :          TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:        TF=0.166            AS=0.166
   LIME RECALCINATION      :          TF=0.166            AS=0.166
   AMMONIA STRIPPING       :          TF=0.166            AS=0.166
   CARBON ABSORPTION       :          TF=0.166            AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         2872.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                42843.3    37818.7    34992.1    32770.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              45716.1    40691.5    37864.9    35643.8

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                             = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.500            AS=0.500
   FILTRATION                :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500            AS=0.500
   LIME RECALCINATION        :          TF=0.500            AS=0.500
   AMMONIA STRIPPING         :          TF=0.500            AS=0.500
   CARBON ABSORPTION         :          TF=0.500            AS=0.500
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                   SUMMARY  OF  SEWAGE  SYSTEM  COSTS
             (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          2872.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0  100[illegible].0

NUMBER OF SYSTEMS REQUIRED:        9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                  52118.8    44399.9    40141.0    36853.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               54991.7    47272.8    43013.8    39726.6

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                       = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                            = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PF1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PF2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=1.000            AS=1.000
   FILTRATION               :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:         TF=1.000            AS=1.000
   LIME RECALCINATION       :          TF=1.000            AS=1.000
   AMMONIA STRIPPING        :          TF=1.000            AS=1.000
   CARBON ABSORPTION        :          TF=1.000            AS=1.000
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
             (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3096.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION         :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526       3810       1905        953

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                              32670.1    30401.2    29032.2    27915.5

TOT PRESENT VALUE
 (INDIV. + CENTRAL)            35766.1    33497.2    32128.2    31011.5

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                              = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :         TF=0.0              AS=0.0
   FILTRATION               :         TF=0.0              AS=0.0
   2-STAGE LIME CLARIFICATION:        TF=0.0              AS=0.0
   LIME RECALCINATION       :         TF=0.0              AS=0.0
   AMMONIA STRIPPING        :         TF=0.0              AS=0.0
   CARBON ABSORPTION        :         TF=0.0              AS=0.0
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
            (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3096.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0     25000.0     50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526        3810        1905         952

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                               35679.6     32537.8     30702.4    29240.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             38775.6     35633.8     33798.4    32336.8

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                               = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                      =  3.5

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   30.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33         ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=0.166            AS=0.166
   FILTRATION               :          TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:         TF=0.166            AS=0.166
   LIME RECALCINATION       :          TF=0.166            AS=0.166
   AMMONIA STRIPPING        :          TF=0.166            AS=0.166
   CARBON ABSORPTION        :          TF=0.166            AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3096.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526       3810       1905        953

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                41736.9    36834.7    34069.1    31916.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              44832.9    39930.7    37165.1    35012.6

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   30.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :           TF=0.500          AS=0.500
   FILTRATION               :           TF=0.500          AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500          AS=0.500
   LIME RECALCINATION       :           TF=0.500          AS=0.500
   AMMONIA STRIPPING        :           TF=0.500          AS=0.500
   CARBON ABSORPTION        :           TF=0.500          AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3096.0 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526       3810       1905        952

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                50803.7    43261.4    39100.8    35909.2

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              53899.8    46357.4    42196.8    39005.2

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                             = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   30.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=1.000          AS=1.000
   FILTRATION                :          TF=1.000          AS=1.000
   2-STAGE LIME CLARIFICATION:          TF=1.000          AS=1.000
   LIME RECALCINATION        :          TF=1.000          AS=1.000
   AMMONIA STRIPPING         :          TF=1.000          AS=1.000
   CARBON ABSORPTION         :          TF=1.000          AS=1.000
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                SUMMARY  OF  SEWAGE  SYSTEM  COSTS
           (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3706.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                33444.7    31126.7    29734.7    28577.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              37151.0    34833.1    33441.0    32283.8

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.0              AS=0.0
   FILTRATION                :          TF=0.0              AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0              AS=0.0
   LIME RECALCINATION        :          TF=0.0              AS=0.0
   AMMONIA STRIPPING         :          TF=0.0              AS=0.0
   CARBON ABSORPTION         :          TF=0.0              AS=0.0
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                    SUMMARY  OF  SEWAGF  SYSTFM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THF TOTAL PRFSENT VALUE CF THE INDIVIDUAL SYSTEM EXPENDITURF STRFAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $        3706.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURF
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                36511.1    33304.5    31437.6    29929.2

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              40217.4    37010.8    35143.9    33635.6

        VALUES  OF  PARAMETERS  USED  FOR  ABOVF  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )
                                                                  = 0.25

PH(PEOPLE PER INDIVIDUAL HOME)
                                                                  =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE CCST OF INDIVIDUAL SYSTEMS AFTER T1)     =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING              :          TF=0.166          AS=0.166
   FILTRATION                  :          TF=0.166          AS=0.166
   2-STAGE LIME CLARIFICATION:            TF=0.166          AS=0.166
   LIME RECALCINATION          :          TF=0.166          AS=0.166
   AMMONIA STRIPPING           :          TF=0.166          AS=0.166
   CARBON ABSORPTION           :          TF=0.166          AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3706.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                42685.4    37683.5    34875.1    32657.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              46391.7    41389.8    38581.4    36364.2

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                             = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.500          AS=0.500
   FILTRATION                :          TF=0.500          AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500          AS=0.500
   LIME RECALCINATION        :          TF=0.500          AS=0.500
   AMMONIA STRIPPING         :          TF=0.500          AS=0.500
   CARBON ABSORPTION         :          TF=0.500          AS=0.500
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
           (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3706.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9768       3907       1954        977

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                51922.3    44236.9    40005.0    36729.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              55628.7    47943.2    43711.3    40436.2

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=1.000            AS=1.000
   FILTRATION                :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:          TF=1.000            AS=1.000
   LIME RECALCINATION        :          TF=1.000            AS=1.000
   AMMONIA STRIPPING         :          TF=1.000            AS=1.000
   CARBON ABSORPTION         :          TF=1.000            AS=1.000
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                 SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          4373.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                31681.9    29483.0    28154.5    27055.2

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              36055.7    33856.8    32528.3    31429.0

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                       = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.0             AS=0.0
   FILTRATION                 :          TF=0.0             AS=0.0
   2-STAGE LIME CLARIFICATION:           TF=0.0             AS=0.0
   LIME RECALCINATION         :          TF=0.0             AS=0.0
   AMMONIA STRIPPING          :          TF=0.0             AS=0.0
   CARBON ABSORPTION          :          TF=0.0             AS=0.0
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          4373.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                               34611.3    31559.5    29777.2    28351.0

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             38985.1    35933.3    34151.0    32724.8

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                      = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                           = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                 =   3.5

H  (PLANNING HORIZON, YEARS)                                  =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)        =   25.
HS (LIFETIME OF SEWER, YEARS)                                 =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                     =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)             =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)           = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)            = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)   =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)    =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.166          AS=0.166
   FILTRATION                :          TF=0.166          AS=0.166
   2-STAGE LIME CLARIFICATION:          TF=0.166          AS=0.166
   LIME RECALCINATION        :          TF=0.166          AS=0.166
   AMMONIA STRIPPING         :          TF=0.166          AS=0.166
   CARBON ABSORPTION         :          TF=0.166          AS=0.166
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                 SUMMARY   OF   SEWAGE   SYSTEM   COSTS
            (EXPRESSED   AS   PRESENT   VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          4373.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                40500.6    35736.2    33054.5    30942.5

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              44874.4    40110.0    37428.3    35316.3

        VALUES   OF   PARAMETERS   USED   FOR   ABOVE   PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                      =  3.5

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)       =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)        =   75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.500            AS=0.500
   FILTRATION                 :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:           TF=0.500            AS=0.500
   LIME RECALCINATION         :          TF=0.500            AS=0.500
   AMMONIA STRIPPING          :          TF=0.500            AS=0.500
   CARBON ABSORPTION          :          TF=0.500            AS=0.500
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                    SUMMARY   OF   SEWAGE   SYSTEM   COSTS
              (EXPRESSED   AS   PRESENT   VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          4373.8 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9230       3692       1846        923

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                49319.4    41989.3    37943.8    34821.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              53693.2    46363.1    42317.6    39195.2

        VALUES   OF   PARAMETERS   USED   FOR   ABOVE   PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)       =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)        =   75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING          :          TF=1.000           AS=1.000
   FILTRATION              :          TF=1.000           AS=1.000
   2-STAGE LIME CLARIFICATION:        TF=1.000           AS=1.000
   LIME RECALCINATION      :          TF=1.000           AS=1.000
   AMMONIA STRIPPING       :          TF=1.000           AS=1.000
   CARBON ABSORPTION       :          TF=1.000           AS=1,000
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                  SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         4961.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                30115.7    28023.0    26750.0    25703.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               35077.0    32984.2    31711.3    30664.6

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                   =    20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)         =    25.
HS (LIFETIME OF SEWER, YEARS)                                  =    50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                      =    20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                 =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)              =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)            = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)             = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)   =    15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)    =    75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :         TF=0.0            AS=0.0
   FILTRATION                 :         TF=0.0            AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0            AS=0.0
   LIME RECALCINATION         :         TF=0.0            AS=0.0
   AMMONIA STRIPPING          :         TF=0.0            AS=0.0
   CARBON ABSORPTION          :         TF=0.0            AS=0.0
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                 (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          4961.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                32917.7    30009.2    28306.6    26933.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              37879.0    34970.5    33267.9    31894.5

       VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                             = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.166            AS=0.166
   FILTRATION                :          TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:          TF=0.166            AS=0.166
   LIME RECALCINATION        :          TF=0.166            AS=0.166
   AMMONIA STRIPPING         :          TF=0.166            AS=0.166
   CARBON ABSORPTION         :          TF=0.166            AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          4961.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :     10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:         8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 38560.3    34008.9    31435.8    29418.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               43521.5    38970.2    36397.0    34379.9

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=    5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                  =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)        =   25.
HS (LIFETIME OF SEWER, YEARS)                                 =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                     =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                =   0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)             =   0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)           = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)            = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)  =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)   =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :         TF=0.500            AS=0.500
   FILTRATION                 :         TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500            AS=0.500
   LIME RECALCINATION         :         TF=0.500            AS=0.500
   AMMONIA STRIPPING          :         TF=0.500            AS=0.500
   CARBON ABSORPTION          :         TF=0.500            AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         4961.3 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        8752       3501       1750        875

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                47004.8    39991.5    36110.8    33125.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             51966.1    44952.8    41072.1    38086.7

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=   5.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                              = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                    =    20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =    25.
HS (LIFETIME OF SEWER, YEARS)                                   =    50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =    20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =    15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =    75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=1.000           AS=1.000
   FILTRATION               :          TF=1.000           AS=1.000
   2-STAGE LIME CLARIFICATION:         TF=1.000           AS=1.000
   LIME RECALCINATION       :          TF=1.000           AS=1.000
   AMMONIA STRIPPING        :          TF=1.000           AS=1.000
   CARBON ABSORPTION        :          TF=1.000           AS=1.000
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3203.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                34596.1    32204.1    30750.0    29568.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               37799.2    35407.1    33953.1    32772.0

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                        = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                             = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :         TF=0.0             AS=0.0
   FILTRATION                 :         TF=0.0             AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0             AS=0.0
   LIME RECALCINATION         :         TF=0.0             AS=0.0
   AMMONIA STRIPPING          :         TF=0.0             AS=0.0
   CARBON ABSORPTION          :         TF=0.0             AS=0.0
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3203.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                37755.3    34447.8    32507.8    30964.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              40958.3    37650.9    35710.9    34167.7

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=    5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)       =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)        =   75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.166            AS=0.166
   FILTRATION                :          TF=0.166            AS=0.166
   2-STAGE LIME CLARIFICATION:          TF=0.166            AS=0.166
   LIME RECALCINATION        :          TF=0.166            AS=0.166
   AMMONIA STRIPPING         :          TF=0.166            AS=0.166
   CARBON ABSORPTION         :          TF=0.166            AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3203.1 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0     25000.0     50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117        4047        2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                44115.0     38962.0     36044.4    33772.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              47318.1     42165.1     39247.4    36975.8

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.500            AS=0.500
   FILTRATION                :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500            AS=0.500
   LIME RECALCINATION        :          TF=0.500            AS=0.500
   AMMONIA STRIPPING         :          TF=0.500            AS=0.500
   CARBON ABSORPTION         :          TF=0.500            AS=0.500
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                   SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3203.1 MILLION.
FOR CENTRAL SYSTEMS:

DESIGN POPULATION         :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:       10117       4047       2023       1012

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                               53632.0    45716.7    41333.5    37976.7

TOT PRESENT VALUE
 (INDIV. + CENTRAL)             56835.1    48919.8    44536.5    41179.7

         VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.25


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                    =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)          =   25.
HS (LIFETIME OF SEWER, YEARS)                                   =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                       =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                  =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)               =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)             = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)              = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)    =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)     =   75.


SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=1.000           AS=1.000
   FILTRATION                :          TF=1.000           AS=1.000
   2-STAGE LIME CLARIFICATION:          TF=1.000           AS=1.000
   LIME RECALCINATION        :          TF=1.000           AS=1.000
   AMMONIA STRIPPING         :          TF=1.000           AS=1.000
   CARBON ABSORPTION         :          TF=1.000           AS=1.000
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                  SUMMARY  OF  SEWAGE  SYSTEM  COSTS
             (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)


THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3551.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                33565.8    31237.4    29832.6    28671.4

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              37117.0    34788.6    33383.8    32222.6

       VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )
                                                                 = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )
                                                                 = 0.33

PH(PEOPLE PER INDIVIDUAL HOME)
                                                                 =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.0            AS=0.0
   FILTRATION                :          TF=0.0            AS=0.0
   2-STAGE LIME CLARIFICATION:          TF=0.0            AS=0.0
   LIME RECALCINATION        :          TF=0.0            AS=0.0
   AMMONIA STRIPPING         :          TF=0.0            AS=0.0
   CARBON ABSORPTION         :          TF=0.0            AS=0.0
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                   SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $        3551.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION        :    10000.0     25000.0     50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:      9801        3920        1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                              36645.7     33423.3     31541.9    30032.3

TOT PRESENT VALUE
 (INDIV. + CENTRAL)            40196.9     36974.5     35093.1    33583.5

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :         TF=0.166           AS=0.166
   FILTRATION                :         TF=0.166           AS=0.166
   2-STAGE LIME CLARIFICATION:         TF=0.166           AS=0.166
   LIME RECALCINATION        :         TF=0.166           AS=0.166
   AMMONIA STRIPPING         :         TF=0.166           AS=0.166
   CARBON ABSORPTION         :         TF=0.166           AS=0.166
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                 (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
   (ADJUSTED FOR SALVAGE VALUE ) IS $         3551.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION           :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:         9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 42843.3    37818.7    34992.1    32770.9

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               46394.5    41369.9    38543.3    36322.1

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
   SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
   HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                   =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   = 0.06
C  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.500            AS=0.500
   FILTRATION                 :          TF=0.500            AS=0.500
   2-STAGE LIME CLARIFICATION:           TF=0.500            AS=0.500
   LIME RECALCINATION         :          TF=0.500            AS=0.500
   AMMONIA STRIPPING          :          TF=0.500            AS=0.500
   CARBON ABSORPTION          :          TF=0.500            AS=0.500
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3551.2 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9801       3920       1960        980

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                52118.8    44399.9    40141.0    36853.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              55670.1    47951.2    43692.2    40405.0

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                              = 0.33


PH(PEOPLE PER INDIVIDUAL HOME)                                    =  3.5

H  (PLANNING HORIZON, YEARS)                                      =  20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =  25.
HS (LIFETIME OF SEWER, YEARS)                                     =  50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =  20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =  15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =  75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING           :          TF=1.000           AS=1.000
   FILTRATION               :          TF=1.000           AS=1.000
   2-STAGE LIME CLARIFICATION:         TF=1.000           AS=1.000
   LIME RECALCINATION       :          TF=1.000           AS=1.000
   AMMONIA STRIPPING        :          TF=1.000           AS=1.000
   CARBON ABSORPTION        :          TF=1.000           AS=1.000
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                    SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3845.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526       3810       1905        953

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                32670.1    30401.2    29032.2    27915.5

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              36515.7    34246.9    32877.9    31761.2

          VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.0             AS=0.0
   FILTRATION                 :          TF=0.0             AS=0.0
   2-STAGE LIME CLARIFICATION:           TF=0.0             AS=0.0
   LIME RECALCINATION         :          TF=0.0             AS=0.0
   AMMONIA STRIPPING          :          TF=0.0             AS=0.0
   CARBON ABSORPTION          :          TF=0.0             AS=0.0
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                     SUMMARY  OF  SEWAGE  SYSTEM  COSTS
                  (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3845.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION           :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:         9526       3810       1905        953

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                 35679.6    32537.8    30702.4    29240.8

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               39525.3    36383.5    34548.0    33086.5

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )
                                                                  = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )
                                                                  = 0.40

PH(PEOPLE PER INDIVIDUAL HOME)
                                                                  =  3.5

H  (PLANNING HORIZON, YEARS)                                     =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)           =   25.
HS (LIFETIME OF SEWER, YEARS)                                    =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                        =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                   =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)              = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)               = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)     =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)      =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=0.166           AS=0.166
   FILTRATION                 :          TF=0.166           AS=0.166
   2-STAGE LIME CLARIFICATION:           TF=0.166           AS=0.166
   LIME RECALCINATION         :          TF=0.166           AS=0.166
   AMMONIA STRIPPING          :          TF=0.166           AS=0.166
   CARBON ABSORPTION          :          TF=0.166           AS=0.166
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                  SUMMARY  OF  SEWAGE  SYSTEM  COSTS
               (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $          3845.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526       3810       1905        953

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                41736.9    36834.7    34069.1    31916.6

TOT PRESENT VALUE
 (INDIV. + CENTRAL)               45582.6    40680.4    37914.8    35762.3

       VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
     SYSTEMS AT START OF PLANNING PERIOD )                         = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
     HOMES USING INDIVIDUAL SYSTEMS )                              = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                      =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)            =   25.
HS (LIFETIME OF SEWER, YEARS)                                     =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                         =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                    = 0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                 = 0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)               = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)      =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)       =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33       ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING            :          TF=0.500          AS=0.500
   FILTRATION                :          TF=0.500          AS=0.500
   2-STAGE LIME CLARIFICATION:          TF=0.500          AS=0.500
   LIME RECALCINATION        :          TF=0.500          AS=0.500
   AMMONIA STRIPPING         :          TF=0.500          AS=0.500
   CARBON ABSORPTION         :          TF=0.500          AS=0.500
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                   SUMMARY  OF  SEWAGE  SYSTEM  COSTS
              (EXPRESSED  AS  PRESENT  VALUE, $ MILLIONS)

THE TOTAL PRESENT VALUE OF THE INDIVIDUAL SYSTEM EXPENDITURE STREAM
    (ADJUSTED FOR SALVAGE VALUE ) IS $         3845.7 MILLION
FOR CENTRAL SYSTEMS:

DESIGN POPULATION          :    10000.0    25000.0    50000.0   100000.0

NUMBER OF SYSTEMS REQUIRED:        9526       3810       1905        953

THE TOTAL PRESENT VALUE ($ MILLIONS) OF THE CENTRAL SYSTEM EXPENDITURE
   STREAM (ADJUSTED FOR SALVAGE VALUE) IS :
                                50803.7    43261.4    39100.8    35909.2

TOT PRESENT VALUE
 (INDIV. + CENTRAL)              54649.4    47107.1    42946.4    39754.9

        VALUES  OF  PARAMETERS  USED  FOR  ABOVE  PROJECTIONS:


T1(YEARS UNTIL INTRODUCTION OF NEW INDIVID. TREATMENT TECHNOLOGY)=   5.
T2(YEARS AFTER INTRODUCTION TO ACHIEVE HALF-MAXIMUM UTILIZATION )=  10.
P (PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL HOMES USING INDIVIDUAL
    SYSTEMS AT START OF PLANNING PERIOD )                          = 0.15
M (MAXIMUM ATTAINABLE PERCENT OF NEWLY CONSTRUCTED INDIVIDUAL
    HOMES USING INDIVIDUAL SYSTEMS )                               = 0.40


PH(PEOPLE PER INDIVIDUAL HOME)                                     =  3.5

H  (PLANNING HORIZON, YEARS)                                       =   20.
HT (LIFETIME OF CENTRAL SYSTEM TREATMENT PLANT, YEARS)             =   25.
HS (LIFETIME OF SEWER, YEARS)                                      =   50.
L  (LIFETIME OF INDIVIDUAL SYSTEM, YEARS)                          =   20.
I  (RATE FOR DISCOUNTING CENTRAL SYSTEM COSTS)                     =  0.06
D  (RATE FOR DISCOUNTING INDIVIDUAL SYSTEM COSTS)                  =  0.06
U1 (INVESTMENT COST OF INDIVIDUAL SYSTEM DURING T1)                = 1000.
U2 (INVESTMENT COST OF INDIVIDUAL SYSTEM AFTER T1)                 = 1250.
PE1(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS DURING T1)       =   15.
PE2(ANNUAL MAINTENANCE COST OF INDIVIDUAL SYSTEMS AFTER T1)        =   75.

SECONDARY TREATMENT BREAKDOWN(DECIMAL PORTION OF CENTRAL SYSTEM):
   TRICKLING FILTER(TF)= 0.33      ACTIVATED SLUDGE(AS)= 0.67

TERT. TRT. BRK.(PORT. OF EACH SECOND. TYPE USING INDICATED TERT. TYPE):
   MICROSCREENING             :          TF=1.000            AS=1.000
   FILTRATION                 :          TF=1.000            AS=1.000
   2-STAGE LIME CLARIFICATION:           TF=1.000            AS=1.000
   LIME RECALCINATION         :          TF=1.000            AS=1.000
   AMMONIA STRIPPING          :          TF=1.000            AS=1.000
   CARBON ABSORPTION          :          TF=1.000            AS=1.000
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III. REDUCTIONS OF BOD DISCHARGED TO SURFACE WATERS AND TREATED WASTEWATERS RETURNED TO SOILS AND GROUNDWATERS

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Soils and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.56	.781	15.0	18.8	22.5
1971	4.81	3.20	1.60	30.8	38.5	46.2
1972	7.42	4.95	2.47	47.5	59.4	71.3
1973	10.0	6.67	3.33	64.0	80.0	96.1
1974	12.6	8.37	4.18	80.4	100	121
1975	15.1	10.1	5.05	96.5	121	145
1976	17.5	11.7	5.84	112	140	168
1977	19.9	13.3	6.63	127	159	191
1978	22.2	14.8	7.40	142	178	213
1979	24.5	16.3	8.16	157	196	235
1980	26.7	17.8	8.90	171	214	257
1981	28.9	19.2	9.62	185	231	277
1982	31.0	20.7	10.3	198	248	298
1983	33.0	22.0	11.0	211	264	317
1984	35.0	23.3	11.7	224	280	336
1985	36.9	24.6	12.3	236	296	355
1986	38.8	25.8	12.9	248	310	372
1987	40.5	27.0	13.5	259	324	389
1988	42.2	28.1	14.1	270	338	405
1989	43.8	29.2	14.6	281	351	421

t_1 = 50 years

P = .15

Base Case

Reduction in Annual BOD Delivered to Surface Streams and

Amount of treated wastewater returned to Soils and Groundwaters

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Soils and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.6	0.75	15	18.8	22.5
1971	4.80	3.2	1.60	30.8	38.5	46.2
1972	7.42	4.9	2.5	47.5	59.4	71.3
1973	10.0	6.6	3.3	64.0	80.0	96.0
1974	12.6	8.4	4.2	80.4	100	120
1975	15.6	10.6	5.2	97.6	123	146
1976	19.2	12.8	6.4	123	165	185
1977	23.3	15.5	7.8	149	186	225
1978	27.9	18.6	9.3	179	223	269
1979	33.1	22.0	11.0	212	265	318
1980	38.7	25.8	12.9	248	310	332
1981	44.8	29.9	14.6	286	358	429
1982	51.2	34.1	17.0	328	410	492
1983	58.0	38.7	19.3	372	465	558
1984	65.1	43.4	21.7	417	531	626
1985	72.4	48.2	24.1	464	580	696
1986	79.8	53.2	26.6	511	639	767
1987	87.3	58.2	29.1	559	699	839
1988	94.8	63.2	31.6	607	759	910
1989	102.4	68.3	34.1	656	820	984

t_1 = 5 years

t_2 = 5 years

P = .15

M = .25 percent

Reduction in Annual BOD Delivered to Surface Streams and

Amount of treated wastewater returned to Soils and Groundwaters.

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Solids and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.56	.781	15.0	18.8	22.5
1971	4.81	3.20	1.60	30.8	38.5	46.2
1972	7.42	4.95	2.47	47.5	59.4	71.3
1973	10.0	6.67	3.33	64.0	80.0	96.1
1974	12.5	8.37	4.18	80.4	100	121
1975	15.8	10.5	5.26	101	126	152
1976	19.7	13.1	6.57	126	158	189
1977	24.4	16.3	8.14	156	196	235
1978	29.9	19.9	9.96	191	239	287
1979	36.2	24.1	12.1	232	290	348
1980	43.3	28.8	14.4	277	346	415
1981	51.0	34.0	17.0	327	408	490
1982	59.4	39.6	19.8	380	475	570
1983	68.3	45.5	22.8	437	546	656
1984	77.6	51.7	25.9	497	621	745
1985	87.2	58.1	29.1	558	698	837
1986	97.0	64.7	32.3	621	776	931
1987	106.9	71.3	35.6	684	856	1027
1988	116.9	77.9	39.0	749	936	1123
1989	126.9	84.6	42.3	813	1016	1219

$t_1 = 5$

$t_2 = 5$

$P = .15$

$M = .33$

Reduction in Annual BOD Delivered to Surface Streams and

Amount of treated wastewater returned to Soils and Groundwaters

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Soils and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.56	.780	15	18.8	22.5
1971	4.81	3.21	1.60	30.8	38.5	46.2
1972	7.42	4.95	2.48	47.5	59.4	71.3
1973	10.0	6.67	[illegible]33	64	80	96
1974	12.5	8.33	4.17	80	100	120
1975	15.9	10.6	5.3	102	128	153
1976	20.1	13.4	6.7	129	161	194
1977	25.3	16.9	8.4	162	203	243
1978	31.5	21.0	10.5	202	253	303
1979	38.9	25.9	13.0	249	311	374
1980	47.2	31.5	15.8	302	378	453
1981	56.4	37.6	18.8	361	451	542
1982	66.5	44.3	22.2	426	533	639
1983	77.3	51.5	25.8	495	619	743
1984	88.8	59.2	29.6	567	709	851
1985	100.3	66.9	33.5	642	803	963
1986	112.2	74.8	37.9	719	899	1079
1987	124.3	82.9	41.5	796	995	1194
1988	136.5	91.0	45.5	874	1093	1311
1989	148.7	99.1	49.5	952	1190	1428

t_1 = 5 years

t_2 = 5 years

P = .15

M = .40

Reduction in Annual BOD Delivered to Surface Streams and Amount of treated wastewater returned to Soils and Groundwaters.

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Soils and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.56	.780	15	18.8	22.5
1971	4.81	3.21	1.60	30.8	38.5	46.2
1972	7.42	4.95	2.48	47.5	59.4	71.3
1973	10.0	6.67	3.33	64	80	96
1974	12.5	8.33	4.17	80	100	120
1975	15.4	10.3	5.1	98.9	124	148
1976	18.6	12.4	6.2	119	149	179
1977	22.1	14.7	7.3	142	178	213
1978	25.9	17.3	8.6	166	208	249
1979	30.1	20.1	10.0	193	241	290
1980	34.6	23.1	11.5	221	276	332
1981	39.4	26.3	13.1	252	315	378
1982	44.5	29.7	14.8	285	356	428
1983	49.9	33.3	16.6	320	400	480
1984	55.6	37.1	18.5	356	445	534
1985	61.5	41.0	20.5	394	493	591
1986	67.5	45.0	22.5	432	540	648
1987	73.7	49.1	24.6	472	590	708
1988	80.0	53.3	26.7	513	641	770
1989	86.5	57.7	28.8	554	693	831

$t_1 = 5$ years

$t_2 = 10$ years

$P = .15$

$M = .25$

Reduction in Annual BOD Delivered to Surface Streams and

Amount of treated wastewater returned to Soils and Groundwaters

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Soils and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.56	.781	15.0	18.8	22.5
1971	4.81	3.20	1.60	30.8	38.5	46.2
1972	7.42	4.95	2.47	47.5	59.4	71.3
1973	10.0	6.67	3.33	64.0	80.0	96.1
1974	12.5	8.37	4.18	80.4	100	121
1975	15.5	10.3	5.17	99.4	124	149
1976	18.9	12.6	6.28	121	151	181
1977	22.6	15.1	7.54	145	181	217
1978	26.8	17.9	8.93	172	215	258
1979	31.5	21.0	10.5	202	252	303
1980	36.7	24.4	12.2	235	294	352
1981	42.3	28.2	14.1	271	339	406
1982	48.4	32.3	16.1	310	387	465
1983	54.9	36.6	18.3	352	440	527
1984	61.8	41.2	20.6	396	495	594
1985	69.1	46.1	23.0	443	553	664
1986	76.7	51.1	25.6	491	614	737
1987	84.5	56.4	28.2	541	677	812
1988	92.6	61.7	30.9	593	741	890
1989	100.9	67.2	33.6	646	807	969

$t_1 = 5$

$t_2 = 10$

$P = .15$

$M = .33$

Reduction in Annual BOD Delivered to Surface Streams and

Amount of treated wastewater returned to soils and groundwaters

	Reduction in BOD Delivered to Surface Streams (thousand tons/yr)			Treated Wastewater Return to Soils and Groundwater (billion gal./yr)		
	85	90	95	80	100	120
1970	2.34	1.56	.780	15	18.8	22.5
1971	4.81	3.21	1.60	30.8	38.5	46.2
1972	7.42	4.95	2.48	47.5	59.4	71.3
1973	10.[illegible]	6.67	3.33	64	80	96
1974	12.5	8.33	4.17	80	100	120
1975	15.6	10.4	5.2	99.7	125	150
1976	19.0	12.7	6.3	122	153	183
1977	23.0	15.3	7.7	147	184	221
1978	27.5	18.3	9.2	176	220	264
1979	32.6	21.7	10.9	209	261	314
1980	38.3	25.5	12.8	246	308	369
1981	44.7	29.8	14.9	286	358	429
1982	51.6	34.4	17.2	330	413	495
1983	59.1	39.4	19.7	378	473	567
1984	67.1	44.7	22.4	430	538	645
1985	75.6	50.4	25.2	484	605	726
1986	84.6	56.4	28.2	542	678	813
1987	93.9	62.6	31.3	601	751	902
1988	103.5	69.0	34.5	663	829	995
1989	111.1	74.0	37.1	712	890	1068

$t_1 = 5$ years

$t_2 = 10$ years

$P = .15$

$M = .40$

Reduction in Annual BOD Delivered to Surface Streams and Amount of treated wastewater returned to Soils and Groundwaters.